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SYNOPSIS
VOLUME I
OF
A DESIGN STUDY OF A HELIUM RECOVERY SYSTEM FOR MILA

John F. Kennedy Space Center
National Aeronautics and Space Administration
NASA Contract No. NAS 10-1472

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Air Products and Chemicals INC.

SYNOPSIS

VOLUME I

OF

"A DESIGN STUDY OF A HELIUM RECOVERY SYSTEM FOR MILA"

John F. Kennedy Space Flight Center

National Aeronautics and Space Administration

[redacted]

Prepared by:

AIR PRODUCTS AND CHEMICALS, INC.

Allentown, Pennsylvania

FOREWORD

This report consolidates the information gathered during Phases I, II, and III of the helium recovery study. The report includes tabulated source data and calculations to support the conclusions presented.

The overall design study consists of three volumes:

Volume I	Synopsis of a Design Study of a Helium Recovery System for MILA.
Volume II	Final Report of a Design Study of a Helium Recovery System for MILA.
Volume III	Helium Usage and Recovery Equipment Supporting Data.

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CHAPTER I

SCOPE AND GROUND RULES

A. SCOPE

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The study described in this report evaluates various methods for recovering and repurifying the helium gas required for the flight preparation and launch of space vehicles at the Merritt Island Launch Area. In addition, it develops and justifies preliminary design for the system(s) considered to be most advantageous. The study is conducted in three phases.

Phase I of this study investigates the quantity and the locations of recoverable helium from the Saturn V - Apollo vehicle operational system at Launch Complex 39, MILA. The helium to be recovered is used for checkout of the Saturn V Space Vehicle at the various areas of LC-39, i.e., the pad area, vertical assembly building (VAB), the converter-compressor facility (CCF), and the various checkout buildings associated with the Apollo Spacecraft. In addition, the usage data was expanded to include the Saturn IB complexes 34 and 37 and associated systems.

Phase II of this study evaluates the various recovery and repurification system concepts and/or combination of concepts for application to the Saturn vehicle operation systems.

Phase III develops and justifies preliminary designs for the system(s) considered to be most advantageous for helium recovery and repurification at MILA.

This study was prepared by Air Products and Chemicals, Inc., under National Aeronautics and Space Administration Contract NAS10-1472.

Author

B. GROUND RULES

The following ground rules and basic assumptions have been established with NASA-KSC for this study.

1. A recovery system is defined as that system which captures and holds contaminated helium, purifies it to Grade A quality, and returns it to the storage facility for reuse.

2. The maximum time that contaminated helium shall remain at Cape Kennedy is 2 weeks, i.e., all contaminated helium in storage must be processed within 2 weeks after a vehicle has been processed either at the pad or the VAB. Contaminated helium is defined as all helium that has been released from storage for checkout and launch purposes and all leakage.

3. Economics shall be based on an amortization period of 10 years and a payout period of 5 years.

4. The cost of helium shall be \$3.50/lb. f.o.b. Amarillo, Texas, or \$4.50/lb. (1) delivered at Cape Kennedy, including 15 days demurrage.

5. Cost of returning contaminated helium from Cape Kennedy to the Bureau of Mines for purification shall be 80% of that charged for shipping Grade A helium to Cape Kennedy. This helium recovery scheme will not be considered in this study.

6. Liquid helium storage or transport shall not be considered in this study. It shall be assumed that helium is delivered to Cape Kennedy in high-pressure railroad cars.

7. The following cost factors shall be used in this study:

   a. Power - 1.225¢/KWH

   b. Water - 10¢/1000 Gallons

   c. Plant operation labor rates:

Classification	Rate (2)	% Fringe Benefits
(1) Superintendent	\$ 192.70/week	20
(2) Assistant Superintendent	161.54/week	20
(3) Operator	3.44/hour	15
(4) Operator Helper	3.24/hour	15
(5) Maintenance Man	3.44/hour	15
(6) Maintenance Helper	3.29/hour	15
(7) Material Handler	2.57/hour	15

(1) See "Report on Long-Range Helium Transportation Optimization Study for NASA, KSC, MILA" by United States Department of the Interior, Bureau of Mines, Helium Activity for a revised cost of helium delivered at Cape Kennedy.

(2) Labor rates listed do not include fringe benefits.

d. Delivered price of cryogenic liquids and propellants to Cape Kennedy shall be as follows:

(1) LN_2 - $ 39.50/ton

(2) LOX - 38.25/ton

(3) LH_2 - 1700/ton ($0.85/lb.)

e. NASA General and Administrative Rate - 10%

f. No interest charge is included for investment funds (cost of capital financing).

8. All helium recovery equipment within the complex except the storage shall be designed to withstand the following (whichever is greater):

a. Overpressure experienced during a normal launch; no allowance is included for a catastrophe.

b. Hurricane wind velocity of 125 mph.

c. The storage containers shall be designed to sustain 75-mile-per-hour winds. For hurricane force winds, it is contemplated that the storage containers will be deflated and covered.

9. The checkout and launch of one Saturn V - Apollo vehicle will normally be performed within a 58-working-day period (one 8-hour shift per day, 5 days per week).* The checkout and launch cycle for one Saturn IB is 40 working days (one 8-hour shift per day, 5 days per week) at Launch Complexes 34 and 37. The checkout and launch procedure for the Saturn IB is to be identical with that of the Saturn V, except for those operations which are duplicated due to the location of the Saturn V at checkout. For example, whereas the Saturn V is pressure tested at both the VAB and the pad, only one such operation is required on the Saturn IB, since all checkout and launch operations are performed at the same location.

10. Utilities are assumed to be available at equipment battery limits.

*According to information received from NASA 3/3/65, the latest schedule for checkout and launch of a Saturn V - Apollo vehicle is 13 weeks; for a Saturn IB, the latest schedule is 58 working days.

CHAPTER II

SUMMARY OF FINDINGS

A. PHASE I - HELIUM USAGE AND AVAILABILITY

The proposed quantity and uses of helium to check out and launch one Saturn V space vehicle at Launch Complex 39 were investigated under Phase I of this study. It was found that the total quantity of Grade A helium required is 69,500 pounds. Of this quantity, 55,300 pounds can be considered recoverable; 2,800 pounds is lost during the flight of the vehicle, and 11,400 pounds is physically lost during checkout and test operations.

Most of the recoverable helium, 27,800 pounds per vehicle, is available at the pad. Lesser amounts are available elsewhere - 25,400 pounds at the VAB, 1,500 pounds at the CCF, and 600 pounds within the industrial area.

The Saturn V - Apollo program also has requirements for Grade AA helium for checkout of the Apollo spacecraft. Since present information is limited as to its availability, its exact purity requirements, and its uses, this source of recoverable helium is excluded from this report. It appears that this quantity is negligible.

Secondary emphasis during this phase was placed on investigating the helium usage associated with the Saturn IB vehicles at Pads 34 and 37. It was found that a total of 16,005 pounds of helium is required to check out and launch one Saturn IB vehicle. Of this amount, it is feasible to recover 13,200 pounds. Flight requirements are 950 pounds.

B. PHASE II - HELIUM RECOVERY SYSTEMS EVALUATION

Evaluation work completed in Phase II of this study was performed in three major steps:

1. Investigation of helium purification cycles.
2. Investigation of contaminated helium gas-holding equipment.
3. Investigation of alternate helium recovery systems.

A general procedure followed throughout Phase II was the inclusion for study of as many different variations as possible for each step. These variations were evaluated by three general criteria: (1) economic advantage, (2) operational difficulty, and (3) amount of development necessary to obtain a workable system.

1. Helium Purification Cycles.

The seven different cycles investigated were:

a. Cases I & IA - Cryogenic Separation and Adsorption at the VAB.

b. Case II - Catalytic Oxidation and Misch Metal Reaction at the Pad.

c. Case III - Catalytic Oxidation and Cryogenic Adsorption at the Pad.

d. Case IV - Catalytic Oxidation and Cryogenic Adsorption at the Pad and the VAB.

e. Case V - Catalytic Oxidation and Ethane Scrub at the VAB and the Pad.

f. Case VI - Thermal Diffusion.

g. Case VII - Gaseous Diffusion.

Cases VI and VII were eliminated because of their high operating cost and because they need further development to become workable.

The remaining cycles were evaluated by relative comparisons, Case IA being used in conjunction with Case II or with Case III to provide a system capable of operation at the VAB and at the pad.

Case IV was found to be the most economical system in this evaluation. However, the combination of Case IA and Case III may have some advantage as the number of launches per year increases. For this reason, it is recommended that Case IV be selected as the best cycle, but that the combination of Case IA and Case III be investigated further in the 12 to 24 launches per year range.

2. Helium Storage Equipment.

The different types of storage (see Figure 1) investigated were:

a. Steel gasholders.
b. Hypalon-coated, double-walled, nylon hemispheres.
c. Urethane-coated, double-walled, nylon half cylinders.
d. Neoprene-coated, double-walled, nylon hemispheres.
e. Steel cylinders at various pressure ratings.
f. Nonrigid airships.

After collecting information from various commercial sources, types a, b, c, and d, above, were evaluated to determine the most economical type of fixed low-pressure storage. Of these, type b appeared to be the best choice, from an economic standpoint and because of ease of maintenance. Helium storage containers of this type (see photograph on page 7) are successfully used at NASA Lewis Research Center. A brief account of the operating experience with this type of storage at this location appears in Appendix A.

An evaluation of storage at higher pressures, type e above (in conjunction with some low-pressure storage for surge), was evaluated for various pressure levels. It was found that low-pressure storage type b, the Hypalon-coated hemisphere, remained the most economical. The nonrigid airships of type f were eliminated because high development costs are involved.

3. <u>Alternate Helium Recovery Systems</u>.

a. Alternate 1 - Fixed plant, fixed low-pressure storage, low-pressure pipeline (Fig. 2)

b. Alternate 2 - Fixed plant, fixed low-pressure storage, high-pressure impure gas trailers (Fig. 3)

c. Alternate 3 - Mobile plant, fixed low-pressure storage, high-pressure pipeline (Fig. 4)

d. Alternate 4 - Mobile plant, fixed low-pressure storage, high-pressure helium trailers (Fig. 5)

e. Alternate 5 - Fixed plant, mobile storage (Fig. 6)

f. Alternate 6 - Mobile plant, fixed low-pressure storage, mobile compressor (Fig. 7)

g. Alternate 7 - Fixed plant, combined storage, low-pressure pipeline (Fig. 8)

Alternate 4 was eliminated immediately because it was duplicated and simplified by Alternate 6. Alternate 5 was eliminated after discussion with Goodyear Tire and Rubber. They indicated that mobile storage would be too expensive because of development costs. The remaining alternates were evaluated by comparison, and the most economical was found to be Alternate 7, a fixed helium purification plant combined with low-pressure storage at the CCF and low-pressure pipelines from the VAB and the pads to storage.

After the recovery systems for Complex 39 were evaluated, a similar investigation was performed on helium recovery and purification for the Saturn IB at Complex 34 and 37. The findings of the previous investigation were used wherever possible in this portion of the

NASA
C-58094

Coated-Nylon Air-Supported Helium Storage Container
Lewis Research Center

study. Four alternate recovery systems were evaluated:

1. Combined low-pressure storage, fixed plant. (Fig. 9)

2. Combined low-pressure storage, high-pressure impure gas trailers, use of plant at Complex 39. (Fig. 10)

3. Combined low-pressure storage, low-pressure pipeline, use of plant at Complex 39. (Fig. 11)

4. Combined low-pressure storage, low-pressure piping from pads to storage, mobile purification plant. (Fig. 12)

The most economical system was found to be the third alternate, which consisted of: (a) combined low-pressure, fixed storage of coated-nylon construction located near the CCF and fed by pipeline from Complex 34 and Complex 37; (b) 1-1/2 inch low-pressure pipeline from this storage to the storage for the purification plant at Complex 39; and (c) use of the purification plant at Complex 39. An incremental cost for the use of this plant is included in Alternates 2 and 3.

C. PHASE III - PRELIMINARY DESIGN OF THE HELIUM RECOVERY SYSTEM

The preliminary design of the helium recovery system, performed in Phase III of this study, consisted of determining optimum storage capacity and plant size, designing an optimum process cycle, and developing cost estimates in relation to launch rates as well as broad design parameters which would guide the development of a satisfactory final design.

Several factors which directly affect the size of low-pressure storage were studied in detail. It was determined that the addition of incremental storage will pay for itself if used but 10 times. The storage has thus been sized to capture all of the helium which it is predicted will be used, and no "use-peaks" will be vented. An ambient temperature of 75°F has been determined from published weather data to be the optimum design temperature. Using plots of the usage pattern for each vehicle operation sequence of interest, a graphical solution was made to determine the most economical combination of plant capacity versus required storage size. Finally, an on-stream factor and usage pattern safety factor were incorporated in the design storage size.

Prior to final preliminary sizing of the process equipment, several studies were undertaken to determine the relative economic advantages of changing certain process conditions to reduce liquid nitrogen consumption. Attention was focused on liquid nitrogen consumption because it constitutes the largest single operating cost. As a direct result of these studies, an additional heat exchanger and a vacuum pump are added in the final process design. The heat exchanger provides additional recovery of refrigeration for precooling, and the vacuum pump permits a lower process stream temperature so that more contained nitrogen is removed by phase separation. In addition, it was determined that the most economical system operating pressure is 155 psia, the lowest possible according to the ground rules. It was also decided to use a nonlubricated compressor in the cycle to prevent poisoning of the deoxo catalyst beds.

The process cycle provides for the removal of hydrogen by catalytic oxidation, forming water, which is removed by condensation and adsorption. Nitrogen is removed by condensing a portion of it at -338°F, and adsorbing the remainder on charcoal at -290°F.

The investment for a helium recovery and purification system composed of a purification plant using the previously described cycle, low-pressure coated-nylon storage containers, low-pressure contaminated helium compressors, and a low-pressure pipeline was calculated for four helium source combinations at four different launch rates each. (See Drawings SK-4-1165-11.1-1D, SK-4-1165-57-1D, SK-4-1165-55.60-1E, SK-4-1165-55.60-2E, and SK-4-1165-55.60-3E for preliminary layout information on the helium purification cold box, helium purification area, and overall helium recovery system.) This investment is found in Figure 13 and ranges from a minimum of $1,629,150 for 4 Saturn V launches per year with recovery at the VAB only, to a maximum of $4,118,940 for 18 Saturn V launches per year and 12 Saturn IB launches per year with recovery at the VAB and at all of the launch pads.

Operating costs as found in Figure 14 include labor, maintenance, chemicals and lubricants, electricity, water, oxygen, and liquid nitrogen and also general and administrative costs on these items.

The combined total of the annual operating costs and the annual depreciation charges divided by the annual weight of helium recovered yields the cost of purification. This cost in dollars per pound of helium recovered, as shown in Figure 15, ranges from a maximum of $3.08/lb. for 4 Saturn V launches per year with recovery at the VAB only, to a minimum of $.58/lb. for 18 Saturn V launches per year and 12 Saturn IB launches per year with recovery at the VAB and at each of the pads.

As shown in Figures 16 and 17, these recovery costs can yield potential savings ranging from a minimum of $142,000 per year, or $1,420,000 for a 10-year program, to a maximum of $4,250,000 per year or $42,500,000 for a 10-year program.

Translated into payout periods, Figure 18 shows all systems considered as acceptable with payout periods of less than 5 years, the limit established in the ground rules of this study.

This study recommends that a helium recovery system be installed at launch Complexes 34, 37, and 39 for recovery of the helium used in the Saturn program.

CHAPTER III

CONCLUSIONS

A. CONCLUSIONS

1. The total quantity of helium gas required for the checkout and launch of one Saturn V - Apollo space vehicle is 69,491 pounds of Grade A quality helium. Of this quantity, it is feasible to recover 52,125 pounds.

2. The total quantity of helium gas required for the checkout and launch of one Saturn IB space vehicle is 16,005 pounds of Grade A quality helium. Of this quantity, it is feasible to recover 12,500 pounds.

3. The most economical helium repurification cycle for Complex 39, MILA, is the catalytic oxidation and cryogenic separation and adsorption cycle.

4. Contaminated helium gas is most economically stored at essentially atmospheric pressure in flexible coated-nylon containers.

5. The most economical helium recovery and repurification system for Launch Complex 39 consists of a helium purification plant (catalytic oxidation and cryogenic separation and adsorption cycle) located at the compressor-converter facility, low-pressure storage located at the compressor-converter facility, and low-pressure piping to the storage from the VAB and from each of the pads.

6. The most economical helium recovery system for Launch Complexes 34 and 37 consists of low-pressure storage at the compressor-converter facility of Complexes 34 and 37 and a low-pressure piping and blower network to transmit the contaminated helium gas from this storage to the low-pressure storage located at the compressor-converter facility of Complex 39. The contaminated helium gas is repurified at the plant located at Launch Complex 39.

7. Helium collection and repurification at the VAB only is economically feasible for launch rates of four or more Saturn V vehicles per year.

8. Helium collection and repurification at the VAB and at the pads of Complex 39 is economically feasible for launch rates of four or more Saturn V vehicles per year.

9. Helium collection and repurification at the VAB and at the pads of Complex 39 and at the pads of Complexes 34 and 37 is economically feasible for launch rates of four or more Saturn V vehicles per year plus six or more Saturn IB vehicles per year.

10. Helium collection and repurification at Complexes 34 and 37 is economically attractive only as part of the recovery system for Complex 39.

11. The total anticipated saving for a 10-year Saturn program ranges from 1.4 million dollars for 4 Saturn V vehicles per year (VAB operation only) to 42.6 million dollars for 18 Saturn V vehicles per year plus 12 Saturn IB vehicles per year (VAB plus pad operation of LC-39 and pad operation of LC-34 and LC-37).

12. The payout period for the helium recovery system investment ranges from a maximum of 3.5 years for VAB operation only at a launch rate of 4 Saturn V vehicles per year to a minimum of 0.8 years for 18 Saturn V vehicles per year.

13. The helium recovery system consisting of the commercially available equipment described herein, can be designed, procured, and erected for operation within a time period of approximately 18 months under normal economic conditions.

14. Safety is a definite consideration when handling hydrogen and hydrogen mixtures. However, pertinent data based on experience is available from many sources. Acceptable standards have been established, and the design and installation of safe hydrogen systems is now common practice. By using commercially available oxygen and hydrogen analyzer-controllers and system vents, and by employing the safety standards established for hydrogen service, combustible hydrogen mixtures within the helium recovery system can positively be avoided. Since the average oxygen composition within the system is in the parts-per-million range, and since the background gas is 90% helium or greater, the maximum allowable concentration of hydrogen that can be tolerated in the system (storage and/or process lines), without the chance of forming a combustible mixture with air entering through a major leak is 8%. Of course any mixture of helium and hydrogen by itself is harmless. (The maximum allowable concentration of hydrogen in a mixture with air without the formation of a combustible mixture is 4.5%.* However, this percentage can be increased to 8% on a helium mixture of 90% helium or higher because of the high thermal conductivity of helium which tends to dissipate the heat of combustion, thereby dampening the combustion reaction.)

15. The vehicle checkout and launch schedules and the quantities of helium used, as presented herein, are considered to be minimum. Should the scheduled checkout and launch periods be lengthened, the quantity of helium used for blanketing per vehicle would increase slightly as would plant operating cost. However, it is felt that more helium will actually be used during the major purge operations, and that the economics and payout period presented in this report would therefore not be adversely affected.

*Bureau of Mines Bulletin, No. 503, page 21.

CHAPTER IV

RECOMMENDATIONS

A. RECOMMENDATIONS

This report recommends that:

1. A helium recovery and repurification system be installed at Launch Complex 39 for Complexes 34, 37 and 39 to recover and repurify the helium used for checkout and launch of the Saturn V and Saturn IB launch vehicles.

2. All contaminated helium gas be stored, prior to repurification, at essentially atmospheric pressure in flexible coated-nylon containers.

3. All contaminated helium gas be transported in pipelines of low-pressure design (approximately 15 psi).

4. The contaminated helium be purified by a plant using a catalytic oxidation and cryogenic separation and adsorption cycle.

5. The helium recovered from LC-39, LC-34, and LC-37 be purified and introduced into the Grade A system at LC-39 for reuse, with makeup helium gas for LC-34 and LC-37 supplied by purchase from the Bureau of Mines.

6. The helium purification system be operated from the control room at the purification plant. The contaminated helium pickup switch valves shall be activated by gas analyzers, which will automatically direct the helium into the system.

7. The pipeline compressors be regulated by pressure indicator controllers.

8. The final design and procurement of equipment for a helium recovery system be started immediately to permit operation of the helium recovery system during the forthcoming Saturn IB program. This permits partial payoff of the recovery system investment prior to the start of the Saturn V launch schedule, and also provides a familiarization and training period for operating personnel.

APPENDIX A

Air Products and Chemicals, Inc. Date: December 30, 1964

TRIP REPORT

of

D. J. Kelemen and D. L. McGinnis

Helium Recovery Study for MILA
NASA Contract Number NAS10-1472
APCI Project No. 00-4-1165

The purpose of this trip was the gathering of information concerning the flexible low-pressure storage containers, used by NASA for the storage of low-pressure helium, as fabricated by Birdair Structures, Inc. of Buffalo, N.Y.

The following summarizes the information obtained from personnel at NASA's Lewis Research Center, Cleveland, Ohio, December 29, 1964.

Tuesday - December 29, 1964 NAS10-1472

Persons Contacted: R. F. Hanlon, NASA
M. Scharer, NASA

After arriving at Lewis Research Center, our initial contact was with Mr. Scharer who briefly described the storage containers and their usage at Lewis and presented us with five black-and-white pictures of these containers. He then introduced Mr. Hanlon who had worked with these containers since their installation at Lewis. After hearing our requirements and stating that all of their problems were connected with contamination of stored pure helium by air permeating through the inner bag at the rate of 140 to 150 ppm per day, they advised that this type of storage should be compatible with our needs. The full report is outlined below.

The two storage containers used at Lewis Research Center are true hemispheres 92 feet in diameter and each capable of containing 200,000 SCF (2000 lb.) of helium at a pressure of approximately 1 inch of water. Each container is composed of an inner hemisphere to contain the helium and an outer hemisphere to provide protection from the weather. The inner hemisphere material is hypalon-coated nylon fabric and as used at Lewis has a laminate of aluminized mylar on the helium or inner side. The outer hemisphere is made of neoprene coated nylon fabric, the outer surface of which is given a final coat of hypalon which acts both as a weathering agent and as a sunlight reflector. Blowers are used to inflate the outer shell with air. The air inside is vented through calibrated vents at the top to prevent accumulation of stagnant air inside, permitting work inside while the shell is inflated. The outer bag has a personnel hatch and two 12-inch windows to allow observation and actual inspection of the helium container while in use. The outer shells are designed for steady 75-mph winds with gusts up to 85 mph. However, the main enemy is not wind but the sun which deteriorates the nylon. This is the eventual cause of failure. The containers now at Lewis are 1 and 4 years old respectively, the 4-year old outer shell having had no maintenance during that time and due for replacement soon. With proper maintenance, painting the outer surface with hypalon every 3 years, the structure can be expected to have a service life of approximately 10 years.

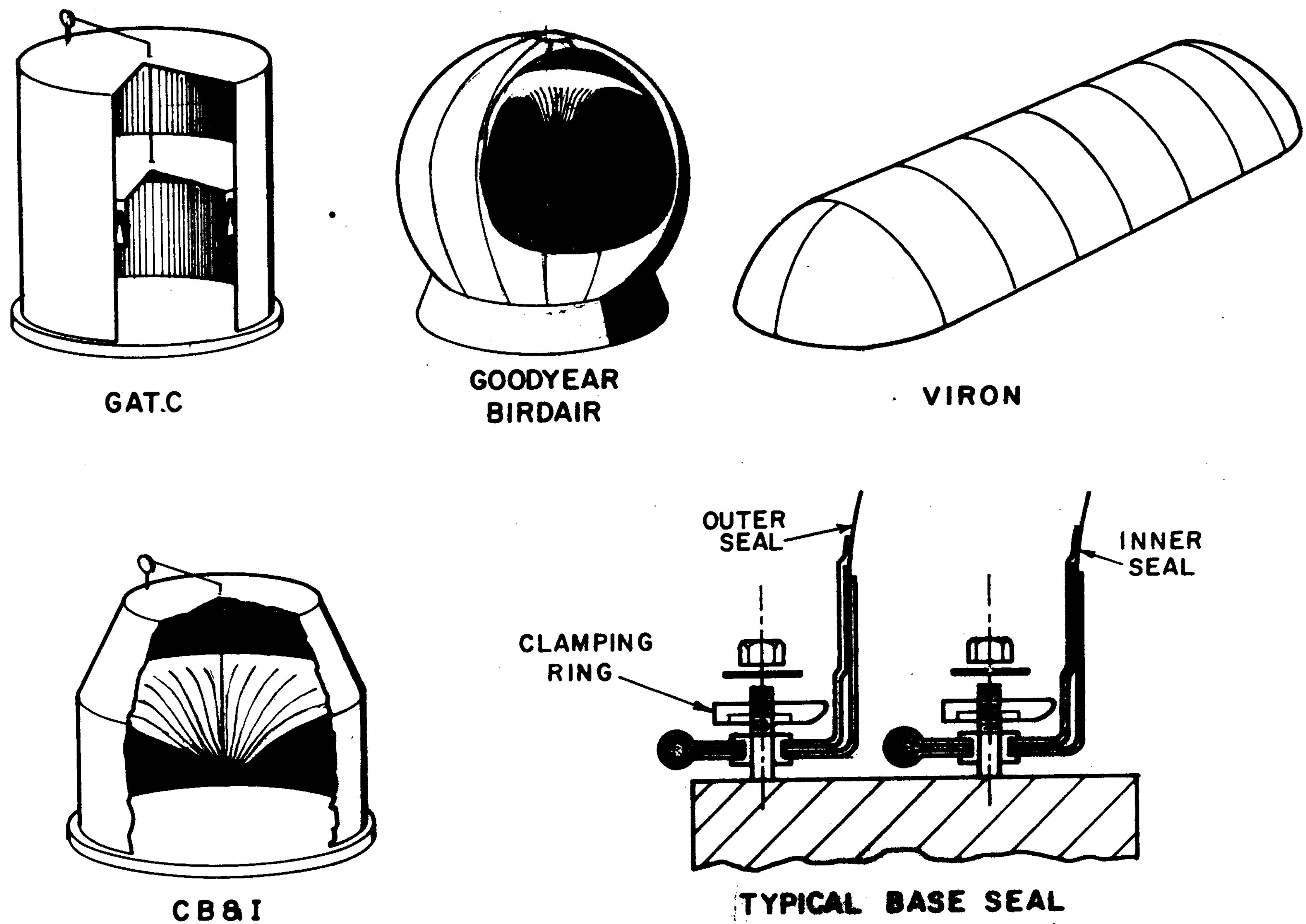
The persistent problem at Lewis with these containers is the permeation of air from the outer shell at 1 to 1-1/2 inches of water into the helium in the inner bag at approximately 0.1 inches of water less than the outer shell pressure. This permeation adds an average of 147 ppm per day of contaminants to the helium. Because of the helium being at a lower absolute pressure than the air in the outer shell, the loss of helium by permeation is minimized.

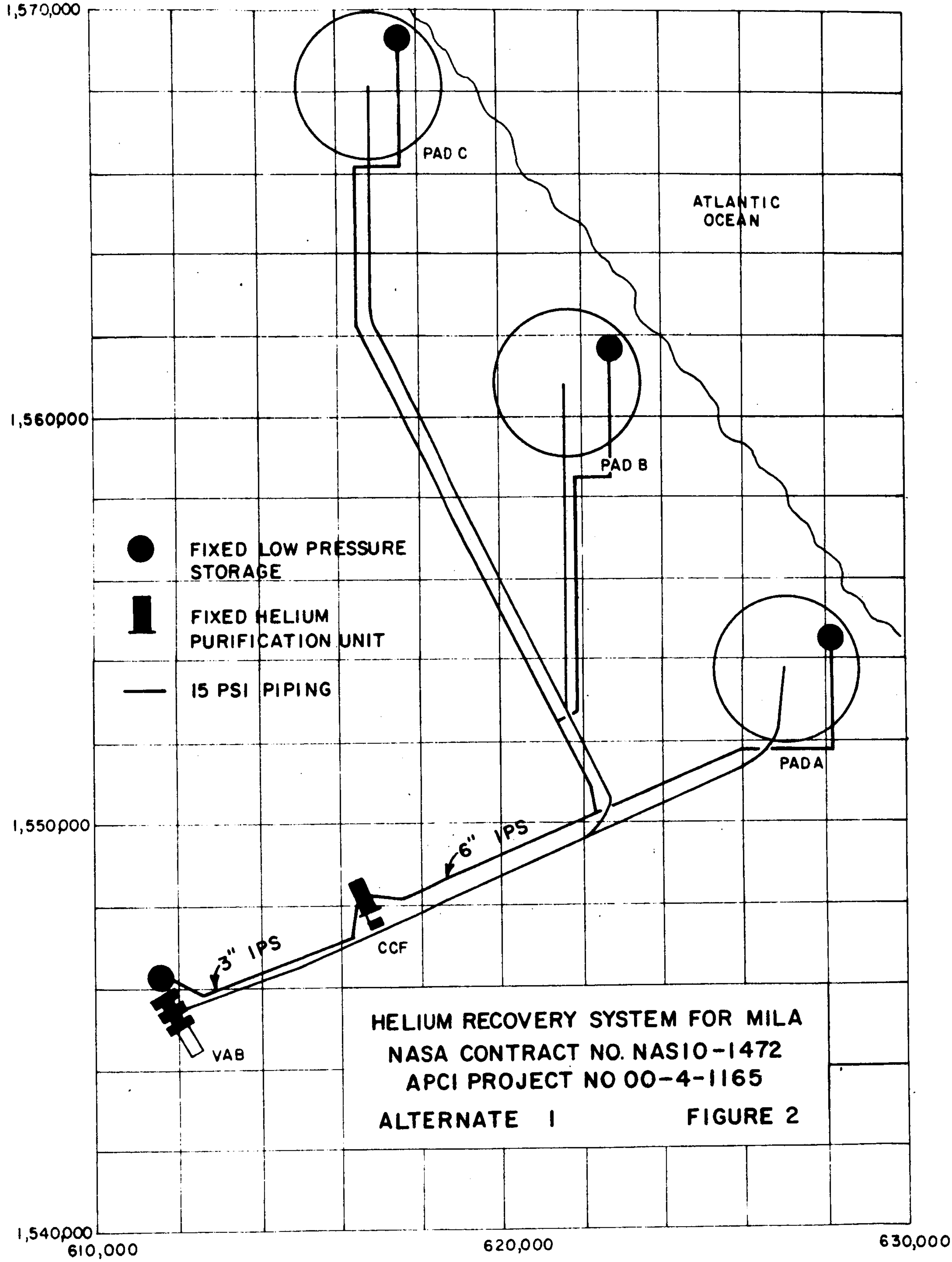
Contamination of the contained helium at the levels mentioned above would not affect the use of these containers for a helium recovery system at MILA. The added level of contamination would not be enough to cause resizing of the purification plant. Other factors such as available compressor sizes and performance ranges would affect plant size more.

Leakage would be less than that lost during gas transfers. During the development of the final design used at Lewis now, there were two failures of the outer shell. Both failures involved failure with hoop or circumferential seams. Adhesive was applied, the seams resealed and a precautionary band cemented over the seams. There have been no further failures of this kind.

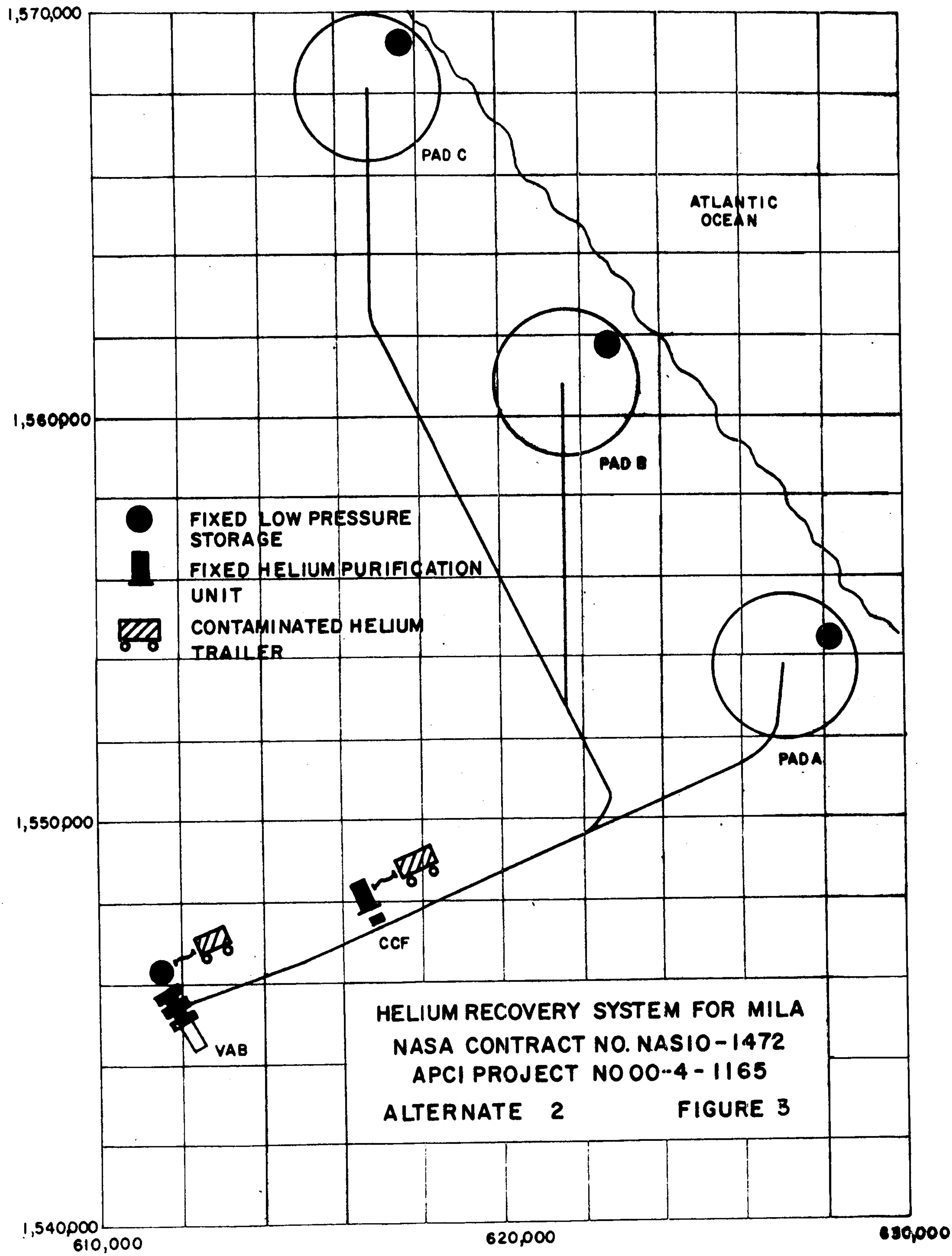
During this failure, as during a blower failure, the outer shell collapsed slowly onto the inner container and remained there while the inner container was collapsed in withdrawing the helium. After all the helium was taken out and both bags lay on the base, repairmen walked out, fixed the defect as described above, and then started the blowers to return the outer shell to normal. The whole procedure can be finished in 5 or 6 hours after the bags have been deflated.

FIGURE 1
LOW PRESSURE STORAGE CONTAINER





HELIUM RECOVERY SYSTEM FOR MILA
NASA CONTRACT NO. NAS10-1472
APCI PROJECT NO 00-4-1165
ALTERNATE I FIGURE 2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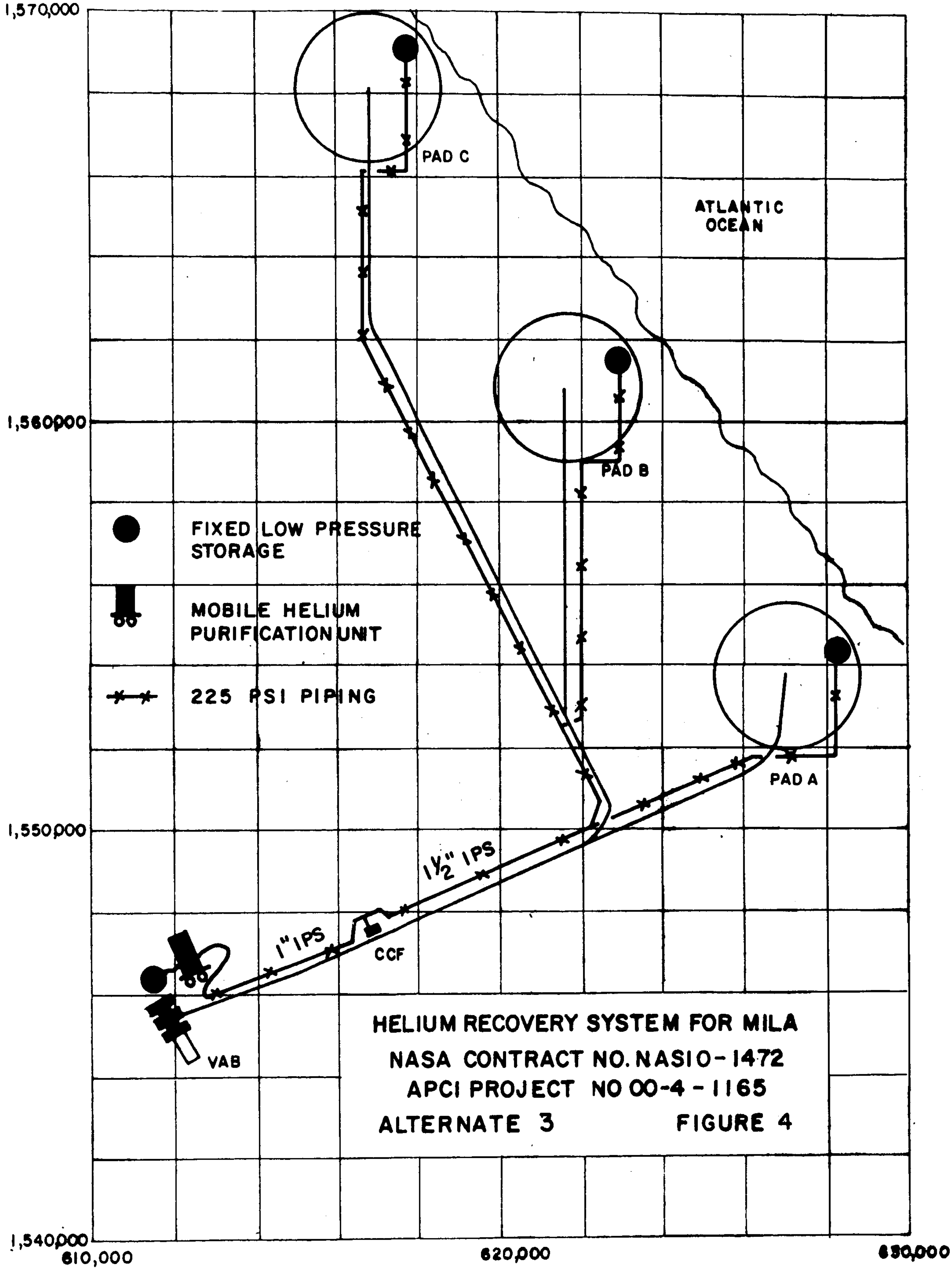
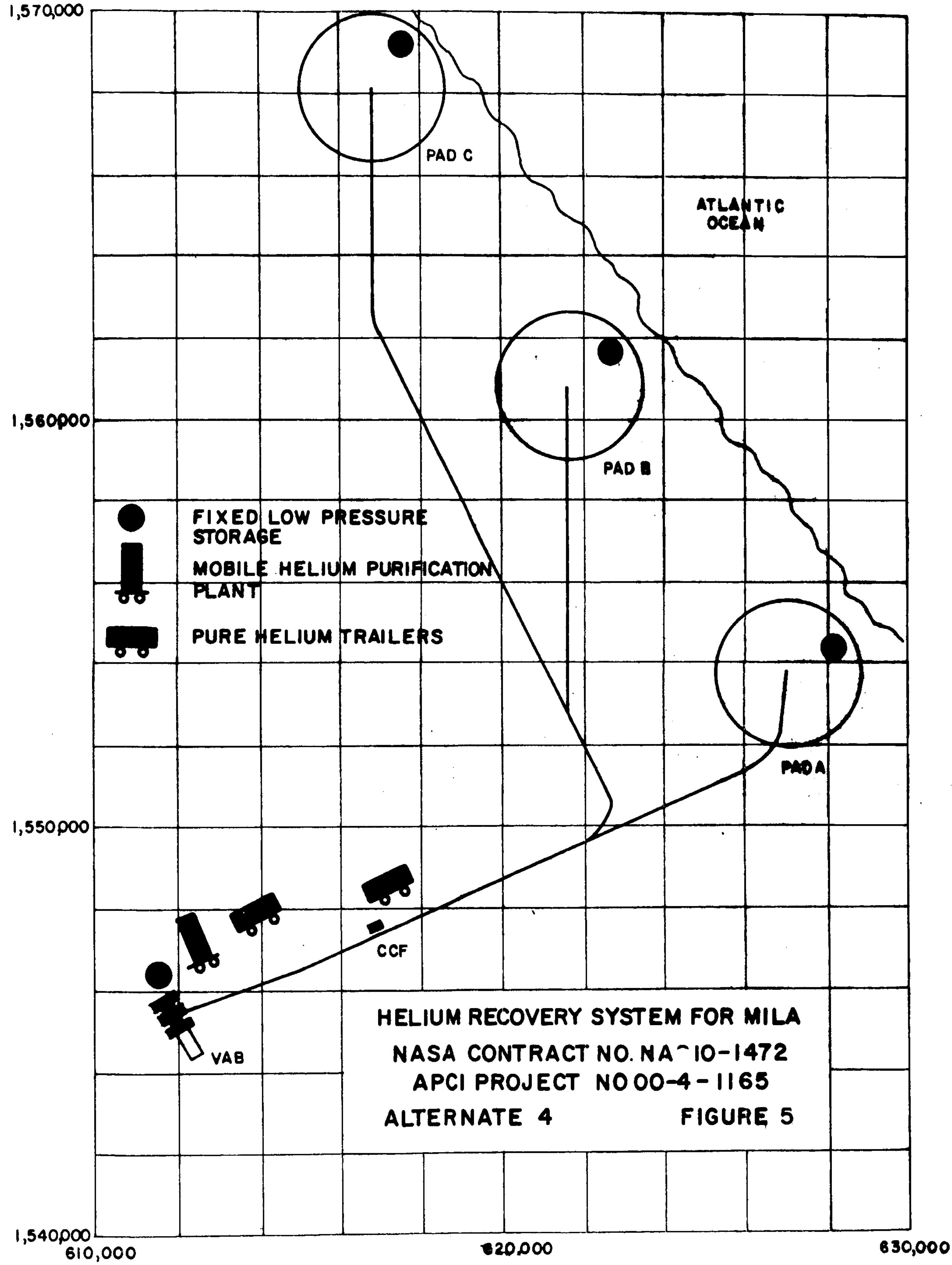
610,000
620,000
630,000
PAD C
ATLANTIC
OCEAN
PAD B
PAD A
FIXED LOW PRESSURE
STORAGE
FIXED HELIUM PURIFICATION
UNIT
CONTAMINATED HELIUM
TRAILER
CCF
VAB
HELIUM RECOVERY SYSTEM FOR MILA
NASA CONTRACT NO. NAS10-1472
APCI PROJECT NO 00-4-1165
ALTERNATE 2
FIGURE 3



HELIUM RECOVERY SYSTEM FOR MILA
NASA CONTRACT NO. NAS10-1472
APCI PROJECT NO 00-4-1165
ALTERNATE 3 FIGURE 4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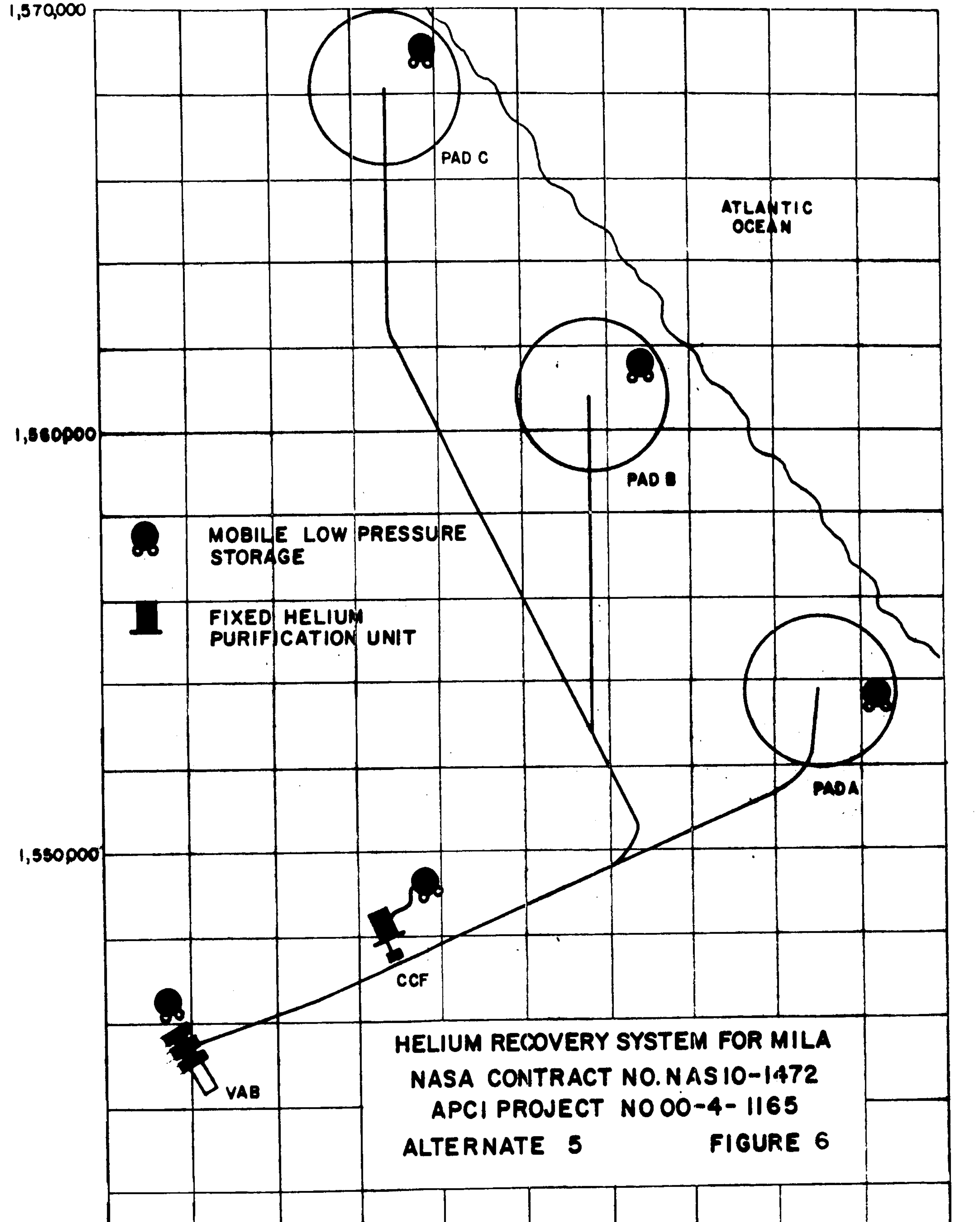
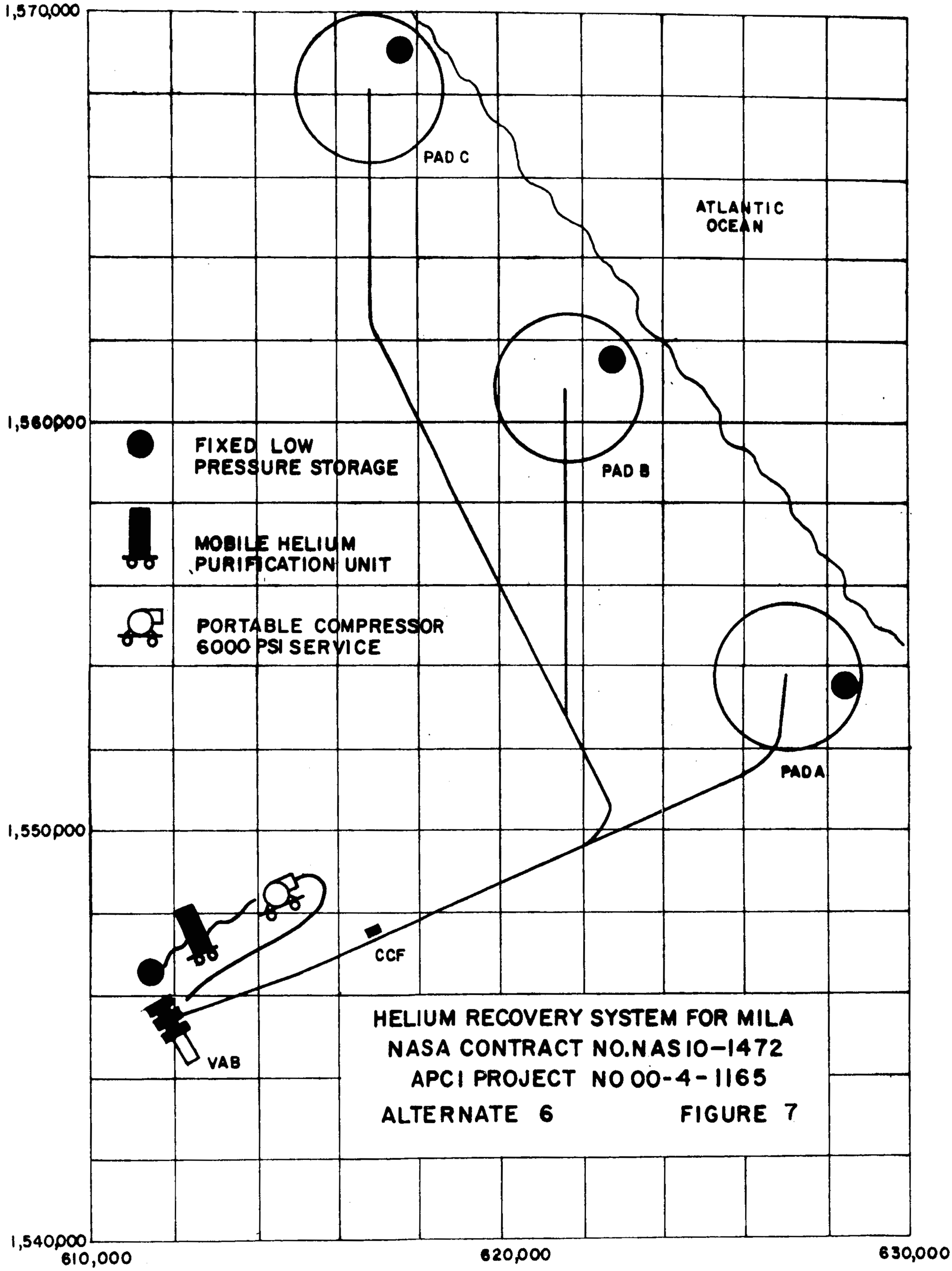
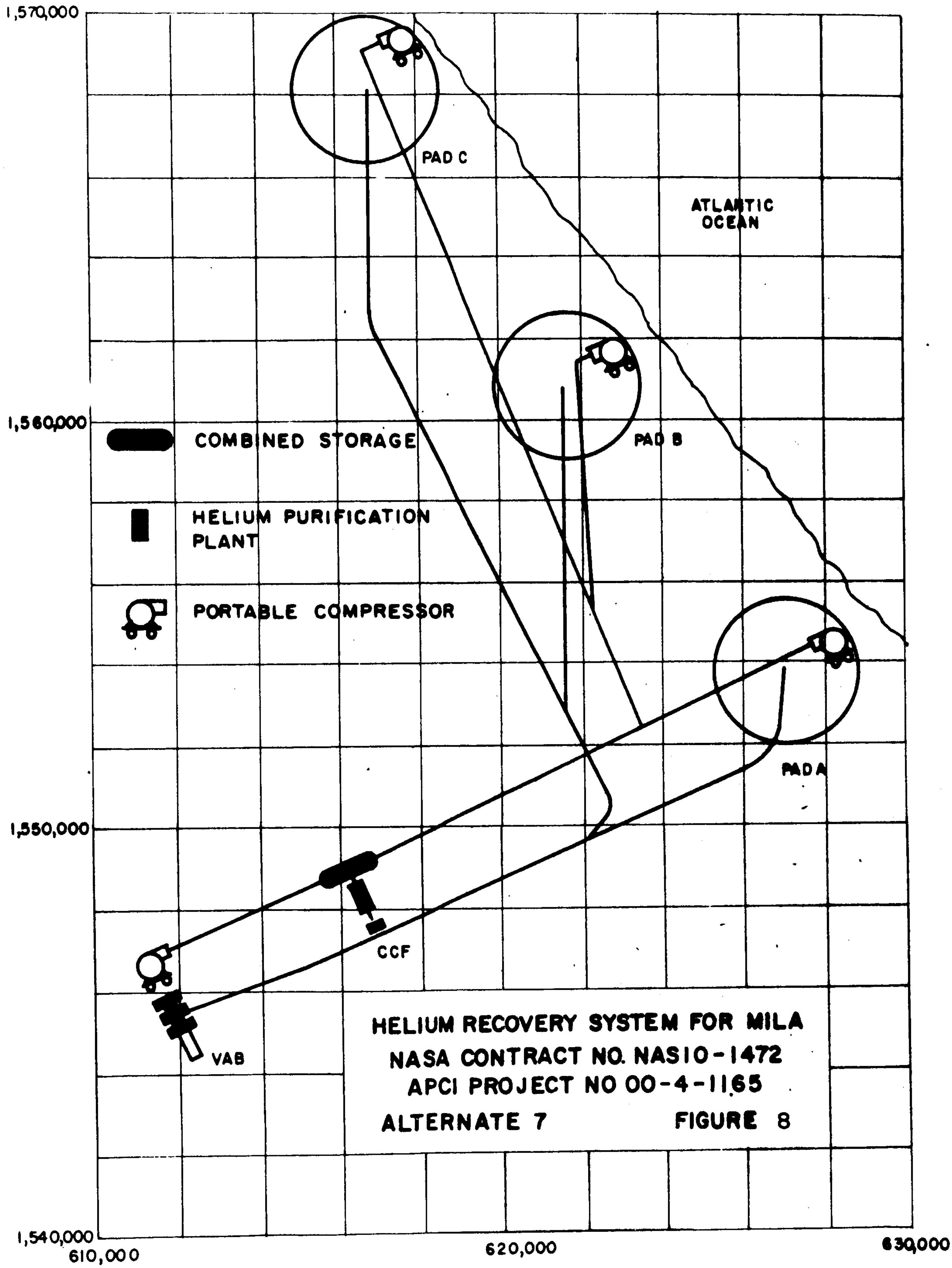
610,000
620,000
630,000
PAD C
PAD B
PAD A
ATLANTIC OCEAN
FIXED LOW PRESSURE STORAGE
MOBILE HELIUM PURIFICATION PLANT
PURE HELIUM TRAILERS
CCF
VAB
HELIUM RECOVERY SYSTEM FOR MILA
NASA CONTRACT NO. NA 10-1472
APCI PROJECT NO 00-4-1165
ALTERNATE 4
FIGURE 5



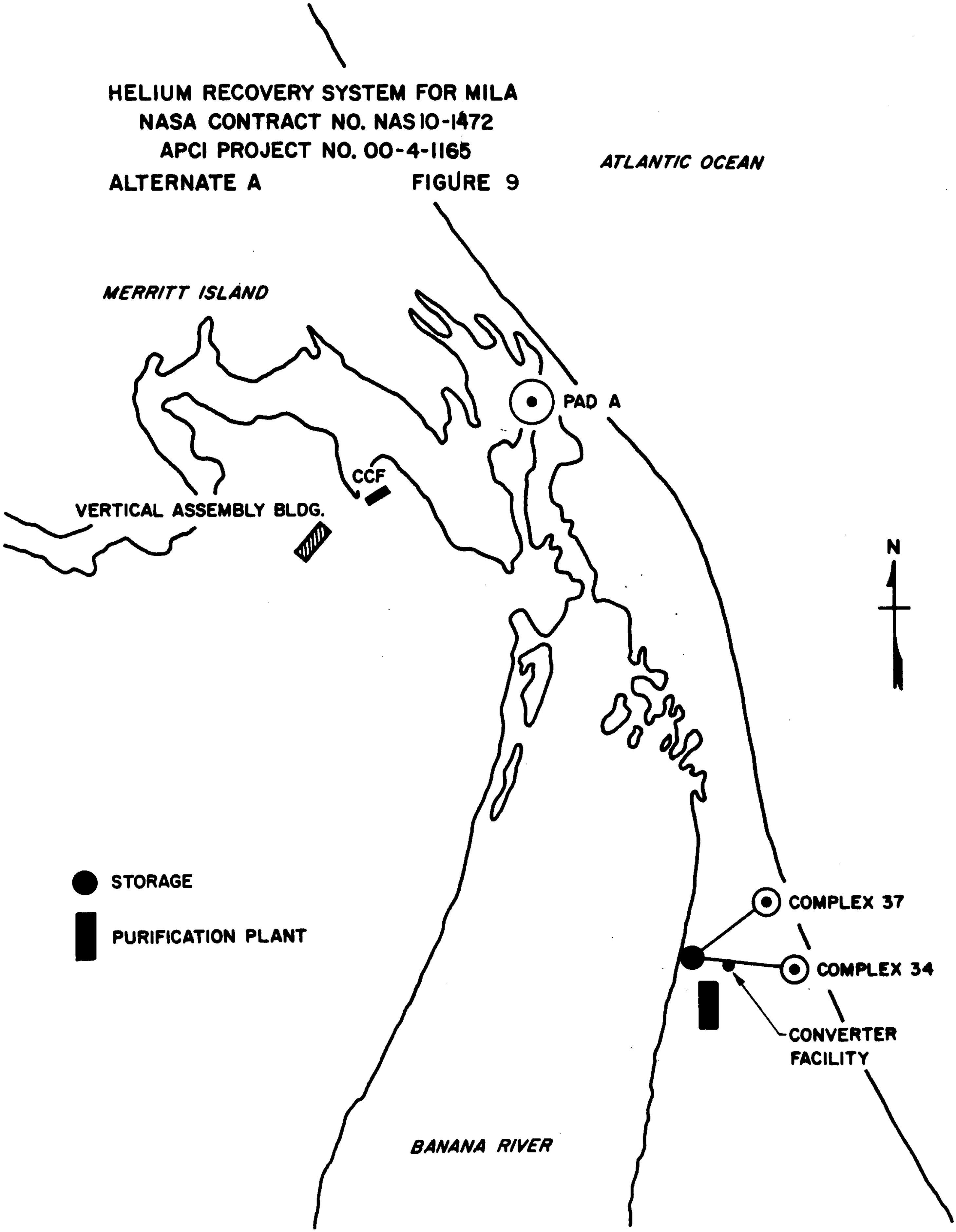
HELIUM RECOVERY SYSTEM FOR MILA
NASA CONTRACT NO. NAS10-1472
APCI PROJECT NO 00-4- 1165
ALTERNATE 5 FIGURE 6

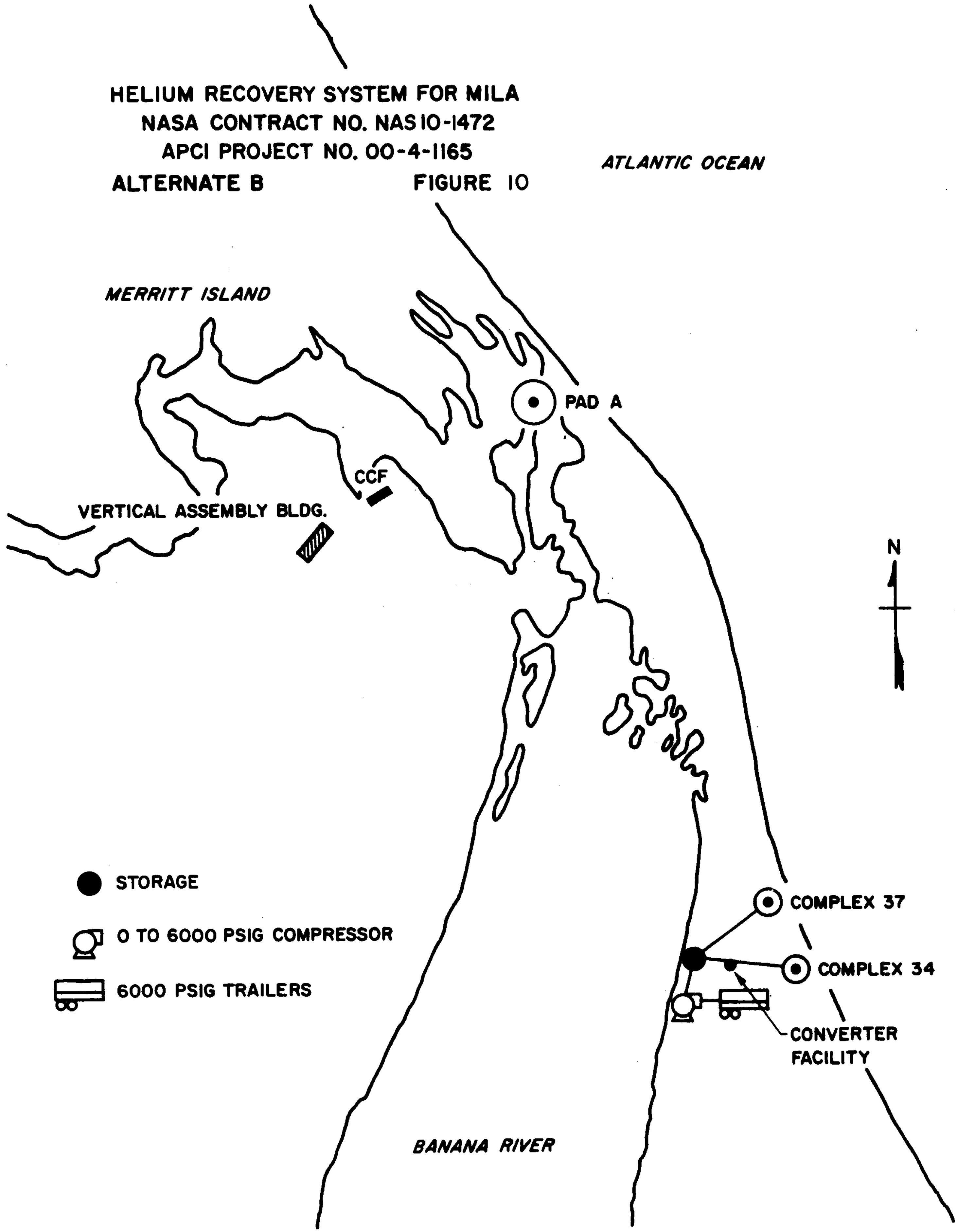


HELIUM RECOVERY SYSTEM FOR MILA
NASA CONTRACT NO. NAS10-1472
APCI PROJECT NO 00-4-1165
ALTERNATE 6 FIGURE 7


1,570,000
1,560,000
1,550,000
1,540,000
610,000
620,000
630,000
PAD C
PAD B
PAD A
ATLANTIC
OCEAN
COMBINED STORAGE
HELIUM PURIFICATION
PLANT
PORTABLE COMPRESSOR
CCF
VAB
HELIUM RECOVERY SYSTEM FOR MILA
NASA CONTRACT NO. NAS10-1472
APCI PROJECT NO 00-4-1165
ALTERNATE 7
FIGURE 8

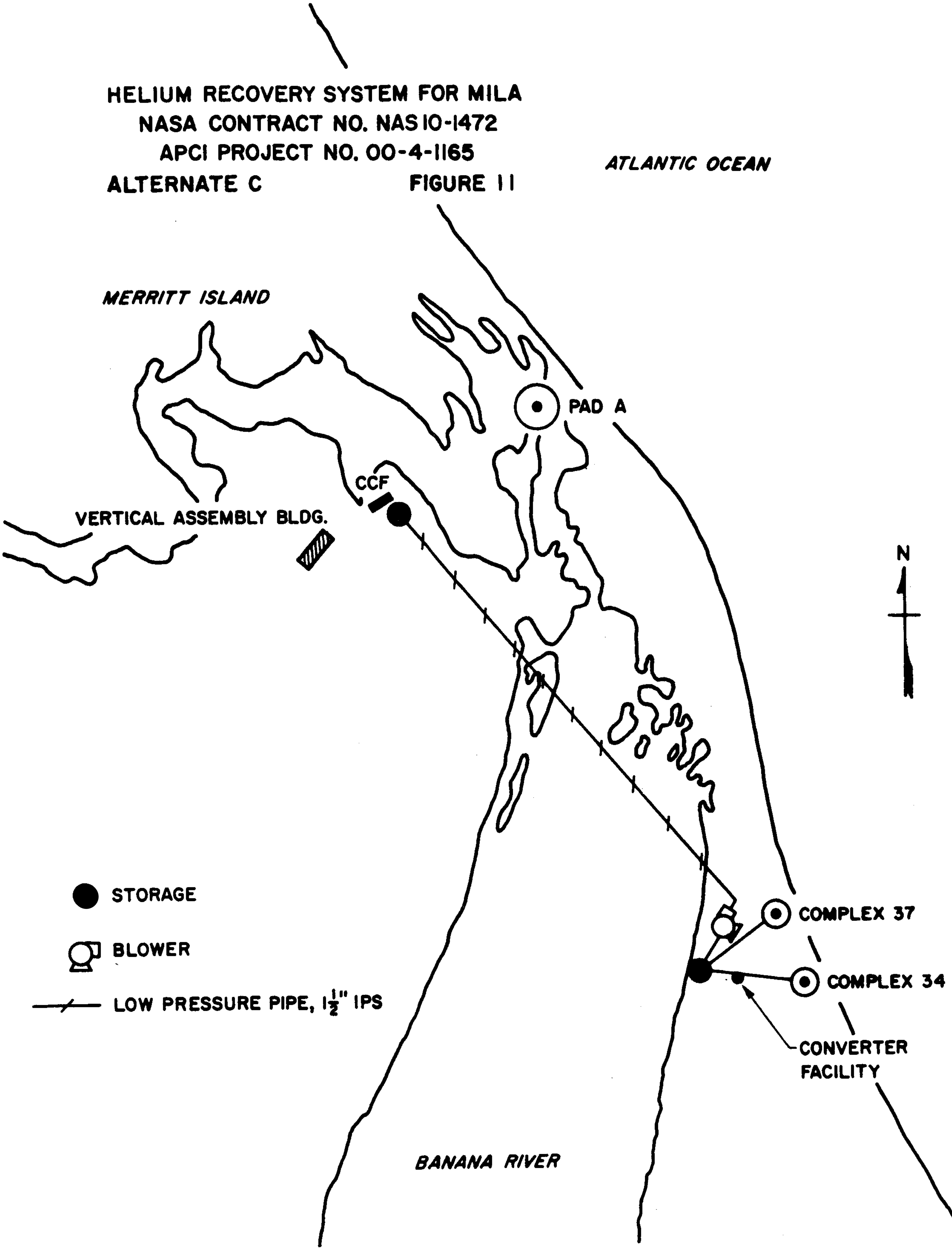
HELIUM RECOVERY SYSTEM FOR MILA
NASA CONTRACT NO. NAS10-1472
APCI PROJECT NO. 00-4-1165
ALTERNATE A FIGURE 9





HELIUM RECOVERY SYSTEM FOR MILA
NASA CONTRACT NO. NAS10-1472
APCI PROJECT NO. 00-4-1165
ALTERNATE B
FIGURE 10

HELIUM RECOVERY SYSTEM FOR MILA
NASA CONTRACT NO. NAS 10-1472
APCI PROJECT NO. 00-4-1165
ALTERNATE C FIGURE 11



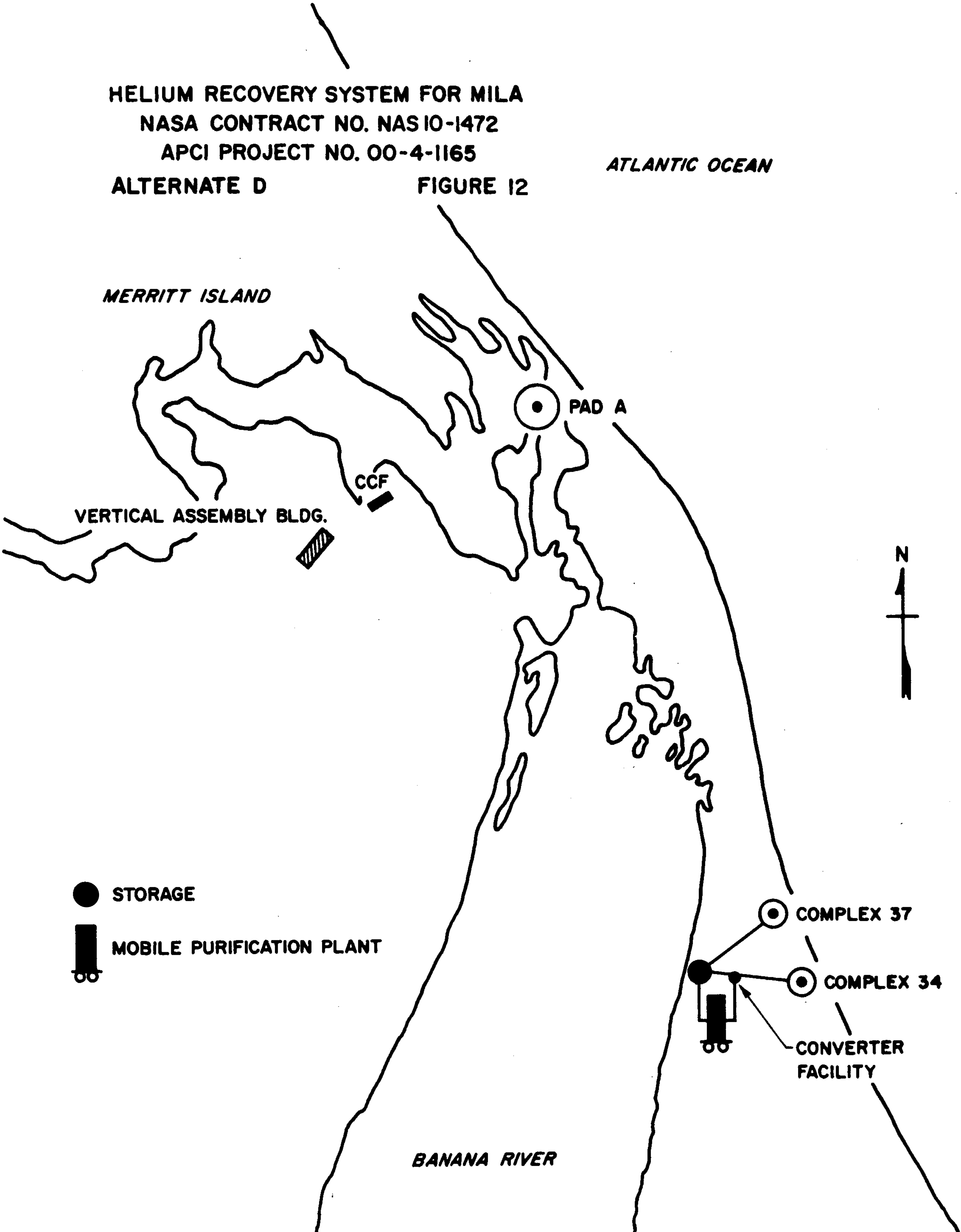
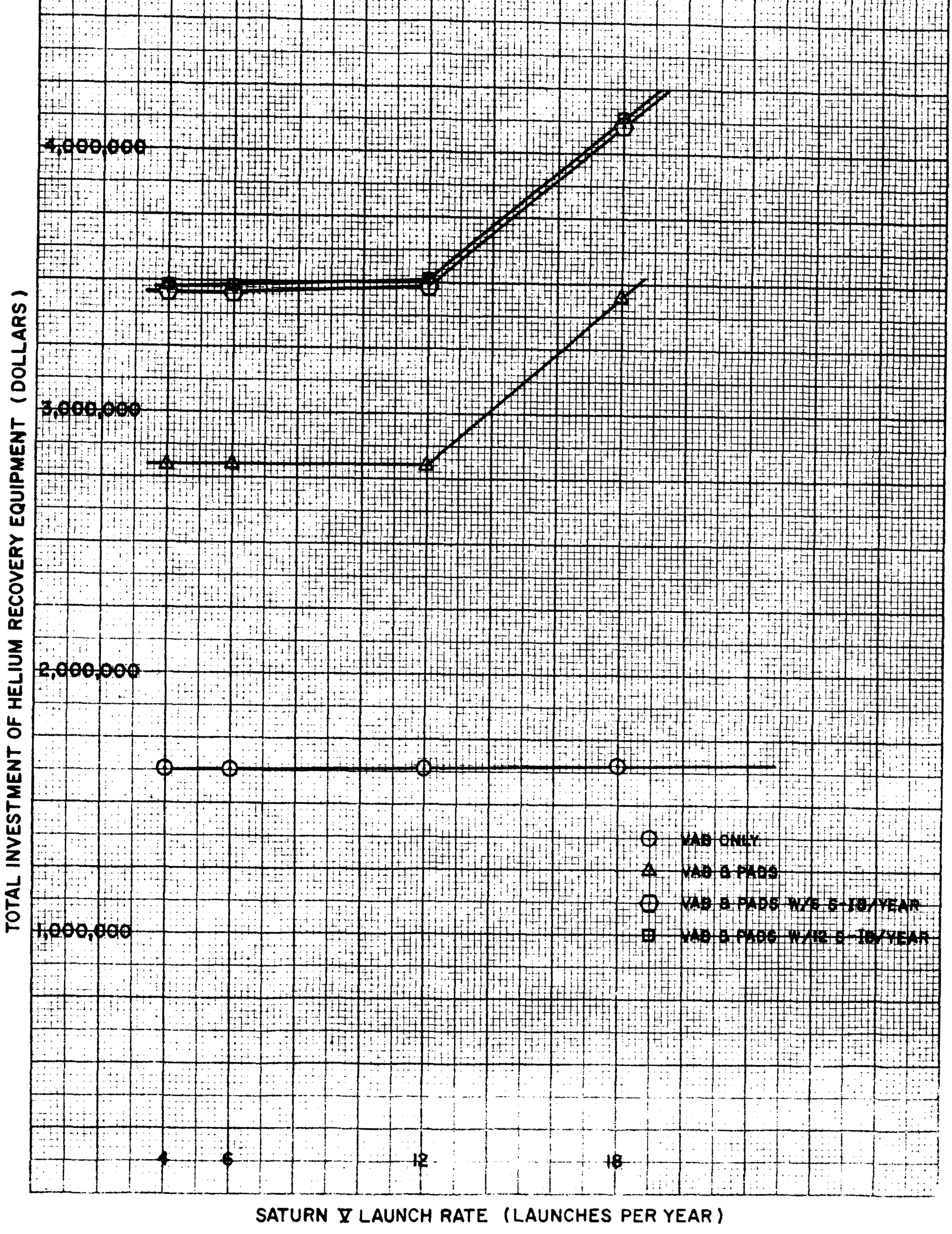

HELIUM RECOVERY SYSTEM FOR MILA
NASA CONTRACT NO. NAS 10-1472
APCI PROJECT NO. 00-4-1165
ALTERNATE D
FIGURE 12
ATLANTIC OCEAN
MERRITT ISLAND
PAD A
CCF
VERTICAL ASSEMBLY BLDG.
N
STORAGE
MOBILE PURIFICATION PLANT
COMPLEX 37
COMPLEX 34
CONVERTER FACILITY
BANANA RIVER

FIGURE NO. 13

TOTAL INVESTMENT OF HELIUM RECOVERY EQUIPMENT



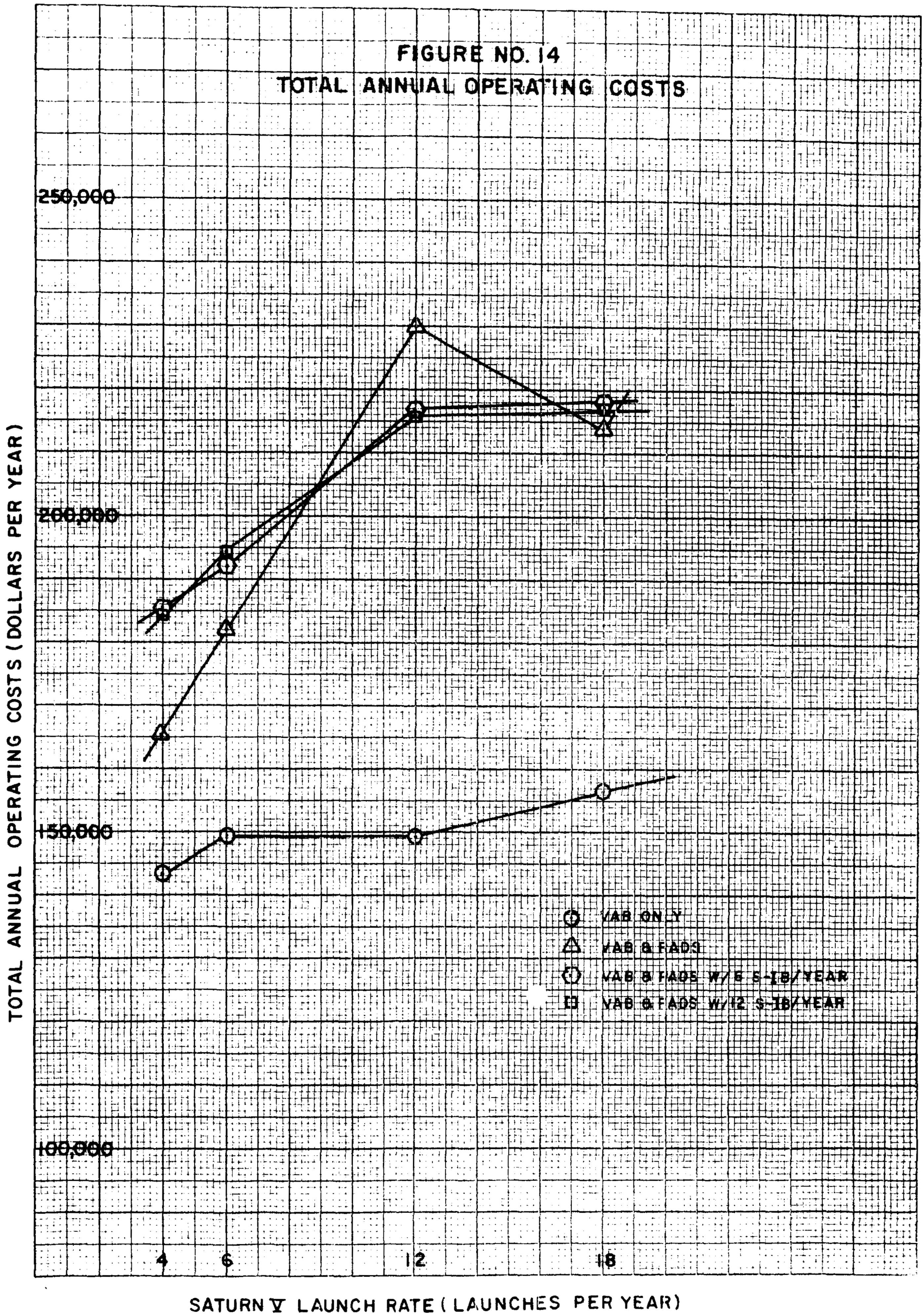


FIGURE NO. 14
TOTAL ANNUAL OPERATING COSTS
250,000
200,000
150,000
100,000
TOTAL ANNUAL OPERATING COSTS (DOLLARS PER YEAR)
4
6
12
18
SATURN V LAUNCH RATE (LAUNCHES PER YEAR)
VAB ONLY
VAB & FADS
VAB & FADS W/6 S-IB/YEAR
VAB & FADS W/12 S-IB/YEAR

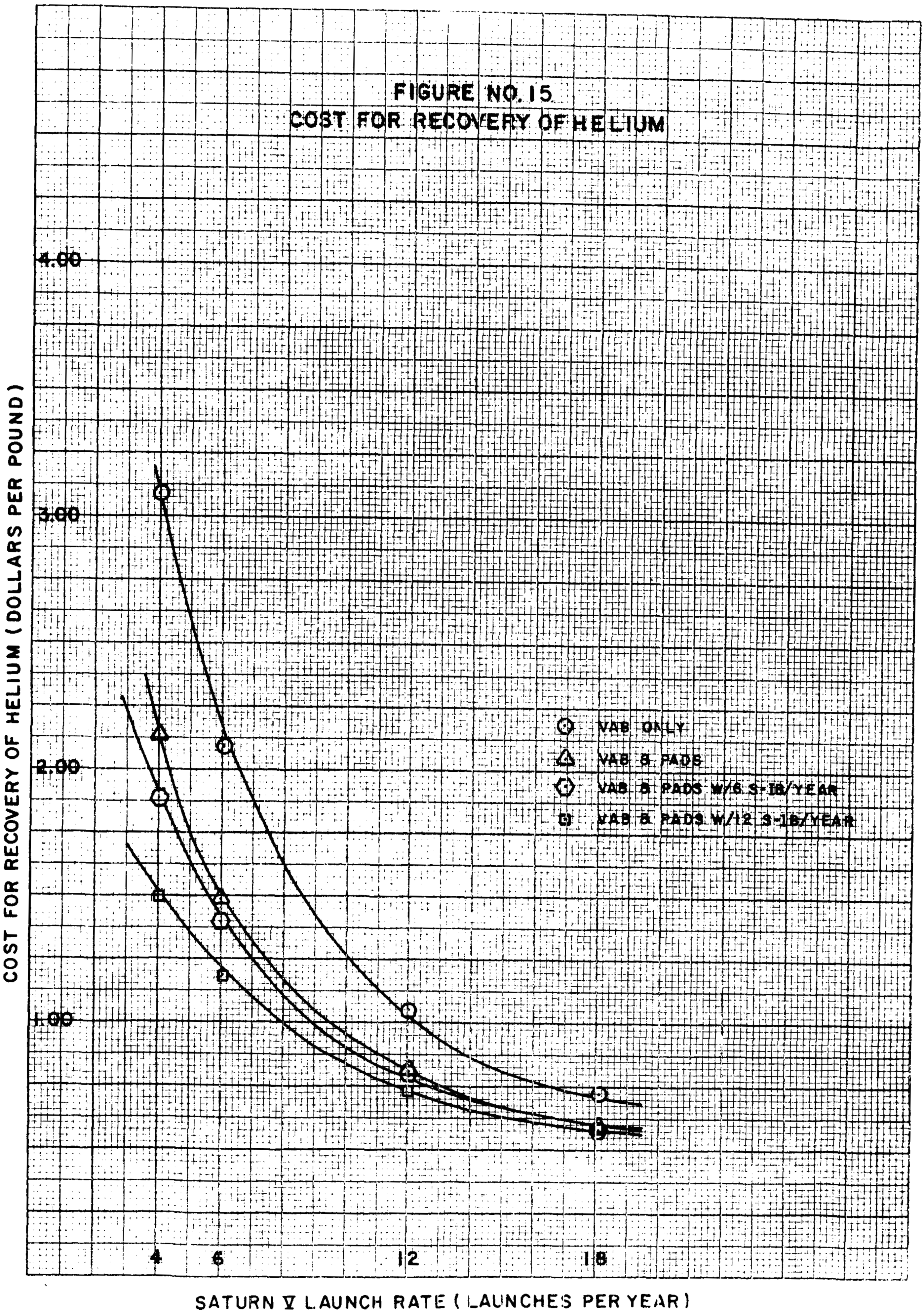


FIGURE NO. 15
COST FOR RECOVERY OF HELIUM
4.00
3.00
2.00
1.00
COST FOR RECOVERY OF HELIUM (DOLLARS PER POUND)
VAB ONLY
VAB & PADS
VAB & PADS W/6 S-IB/YEAR
VAB & PADS W/12 S-IB/YEAR
4
6
12
18
SATURN V LAUNCH RATE (LAUNCHES PER YEAR)

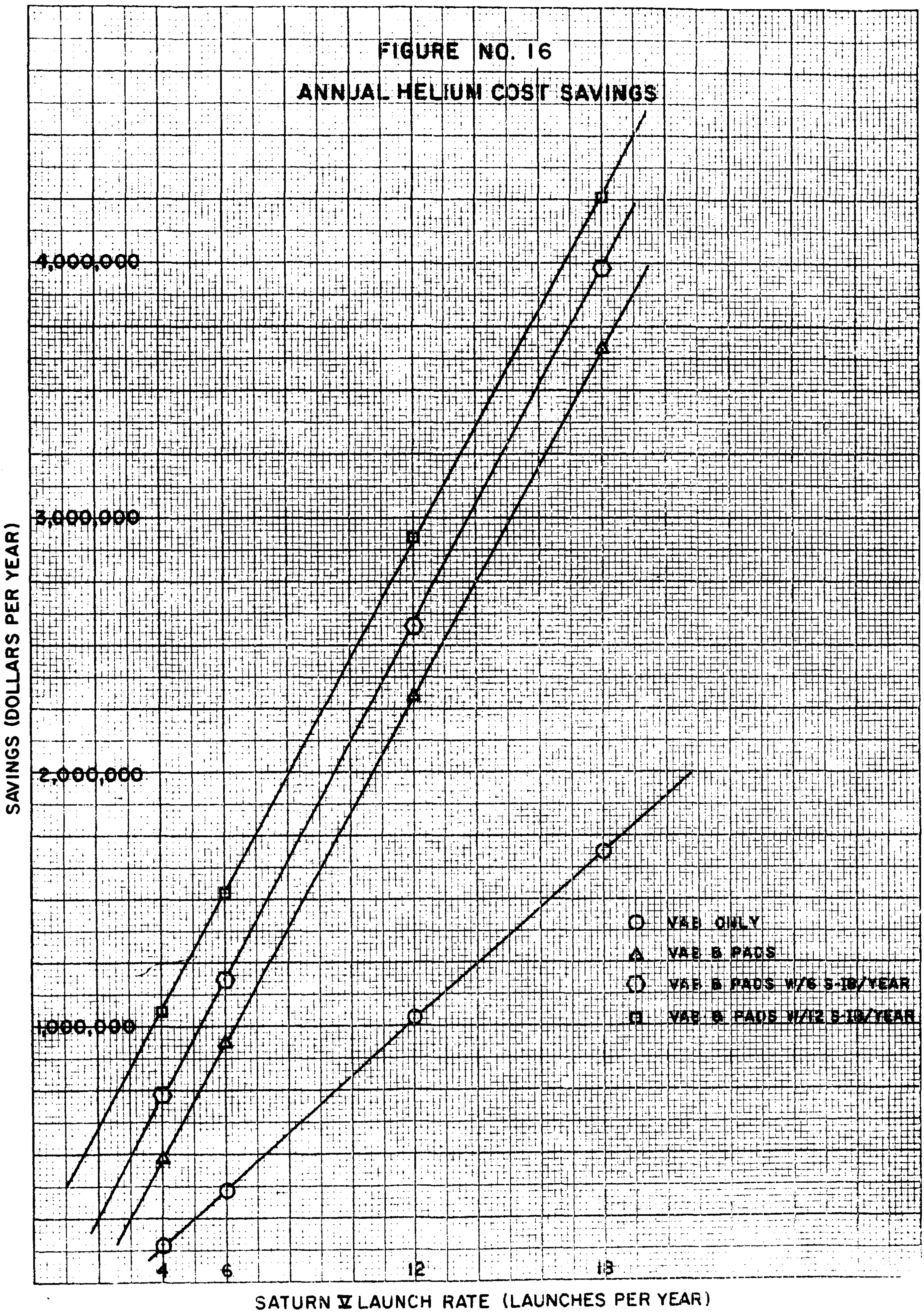


FIGURE NO. 16
ANNUAL HELIUM COST SAVINGS
4,000,000
3,000,000
2,000,000
1,000,000
SAVINGS (DOLLARS PER YEAR)
4
6
12
18
SATURN V LAUNCH RATE (LAUNCHES PER YEAR)
VAB ONLY
VAB & PADS
VAB & PADS W/6 S-IB/YEAR
VAB & PADS W/12 S-IB/YEAR

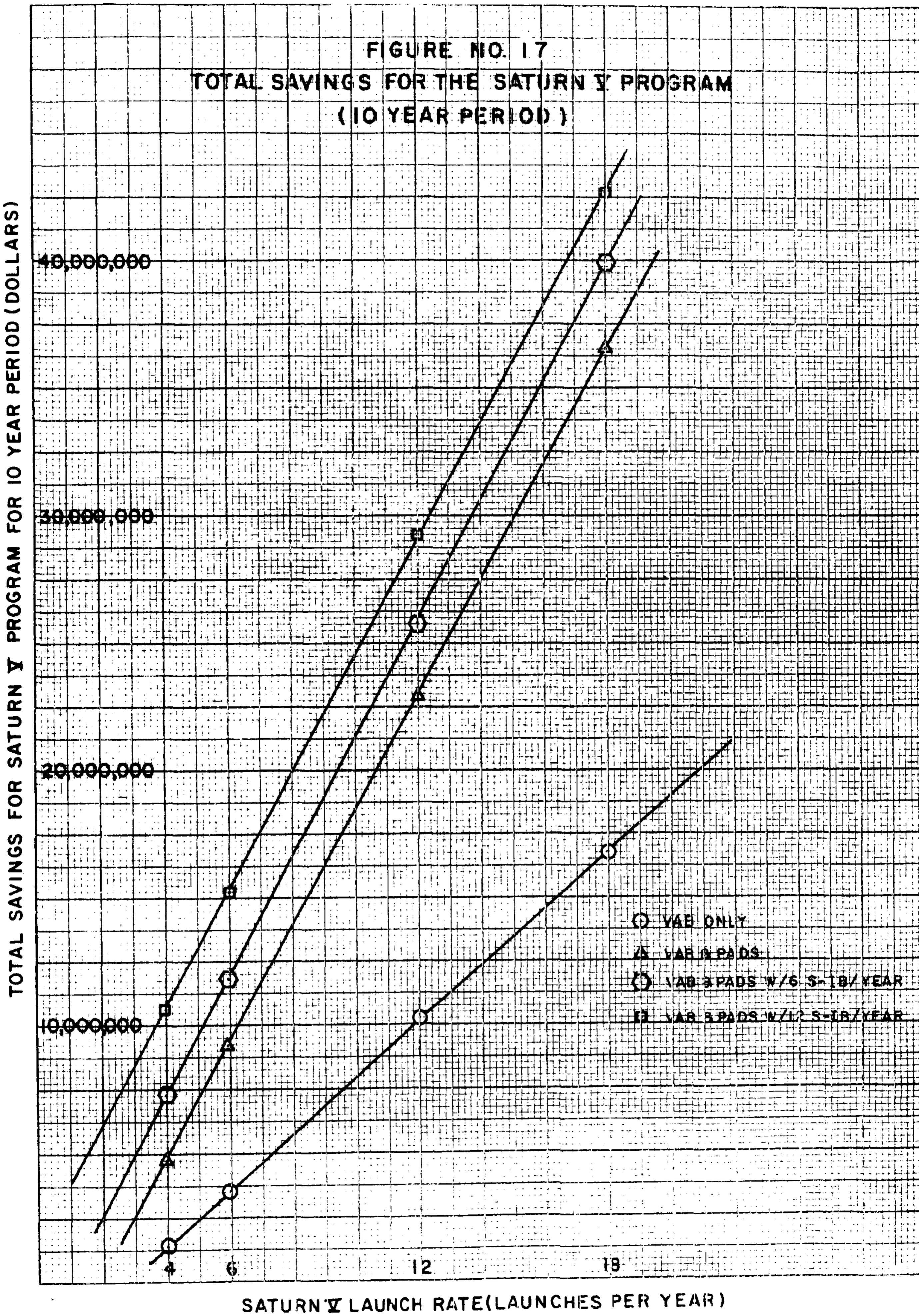


FIGURE NO. 17
TOTAL SAVINGS FOR THE SATURN V PROGRAM
(10 YEAR PERIOD)

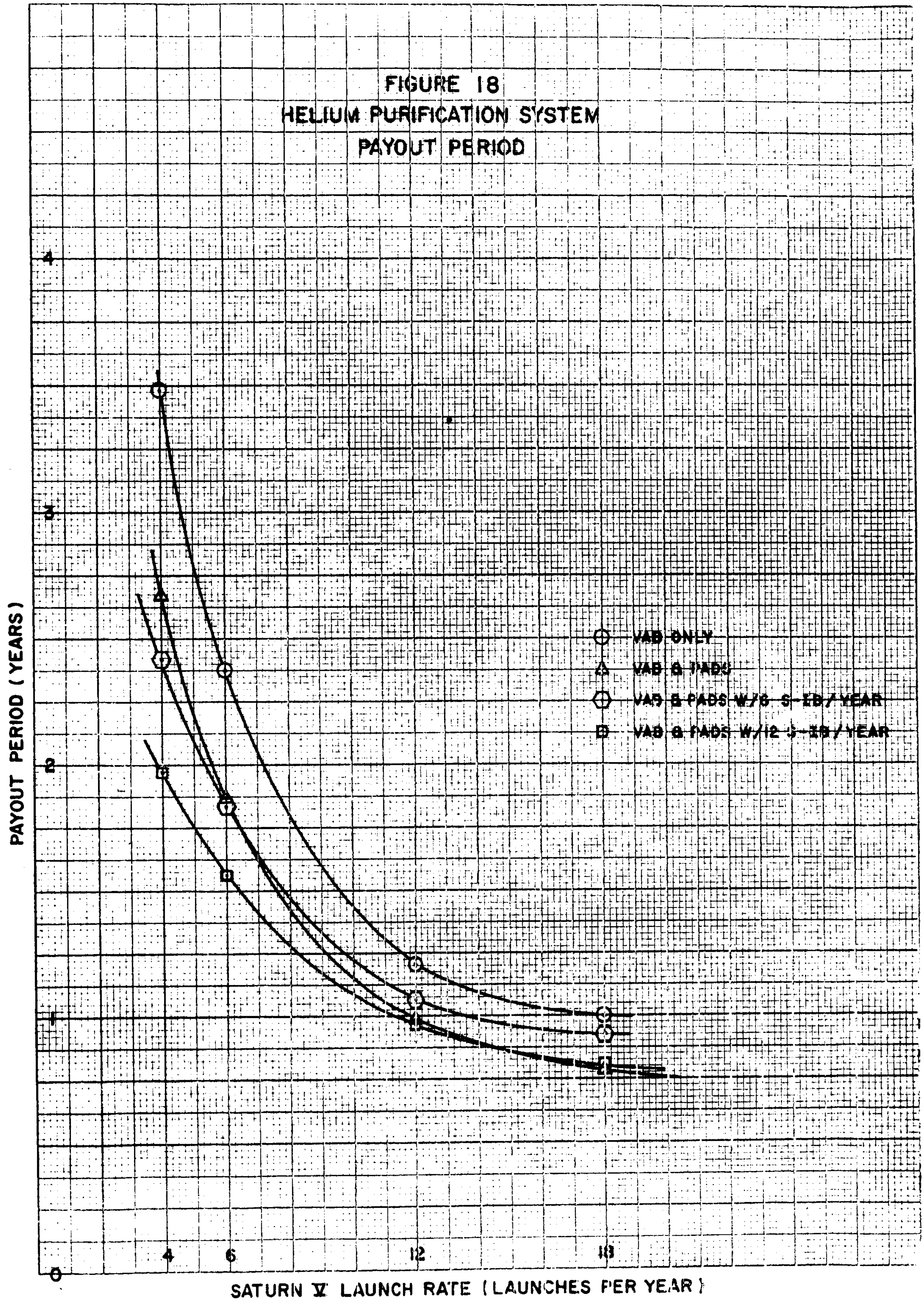
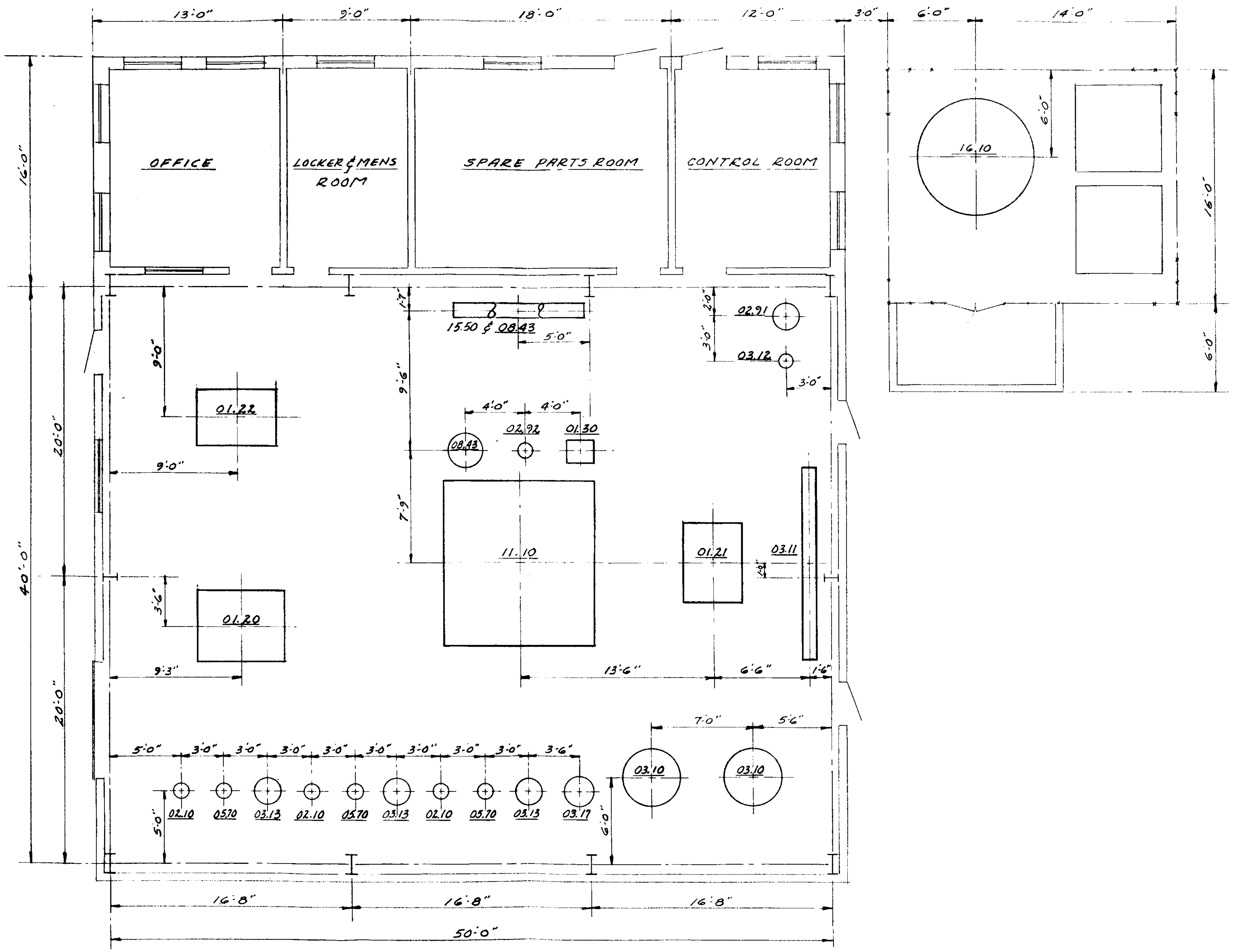


FIGURE 18
HELIUM PURIFICATION SYSTEM
PAYOUT PERIOD
PAYOUT PERIOD (YEARS)
0
1
2
3
4
4
6
12
18
SATURN V LAUNCH RATE (LAUNCHES PER YEAR)
VAB ONLY
VAB & PADS
VAB & PADS W/6 S-IB/YEAR
VAB & PADS W/12 S-IB/YEAR



LEGEND

01.20 MAIN COMPRESSOR
01.21 DRIER REACTIVATION COMPRESSOR
01.22 ADSORBER REACTIVATION COMPRESSOR
01.30 NITROGEN VACUUM PUMP
02.10 DEOXO CONVERTER
02.90 FILTER
02.91 FILTER
02.92 FILTER
03.10 DRIER
03.11 WATER COOLER
03.12 WATER SEPARATOR
03.13 WATER SEPARATOR
03.17 HEATER
05.70 COOLER
08.23 WATER HEATER
08.43 ADSORBER HEATER
15.50 DEFROST WATER HEATER
16.10 LIN STORAGE TANK & VAPORIZERS

SK-4-1165-57-1 D

REVISIONS							
NO.	LETTER	ZONE	DESCRIPTION	DATE	MADE	CHK'D	APPR'D

PART NO.	MAT'L. CODE NO.	QTY.	DIMENSIONS	REMARKS	NOMENCLATURE

UNLESS OTHERWISE SPECIFIED TOLERANCES ARE: FRACTION ± DECIMAL ± ANGLES ± HOLE LOCATION ± HOLE SIZE ±

FIRST USED ON: 00-4-1165-57.

DRAFTSMAN: D.A. HAFER — DATE 2-18-65
CHECKED:
ENGINEER:
APPR'D: W. Cuhne — 2/18/65

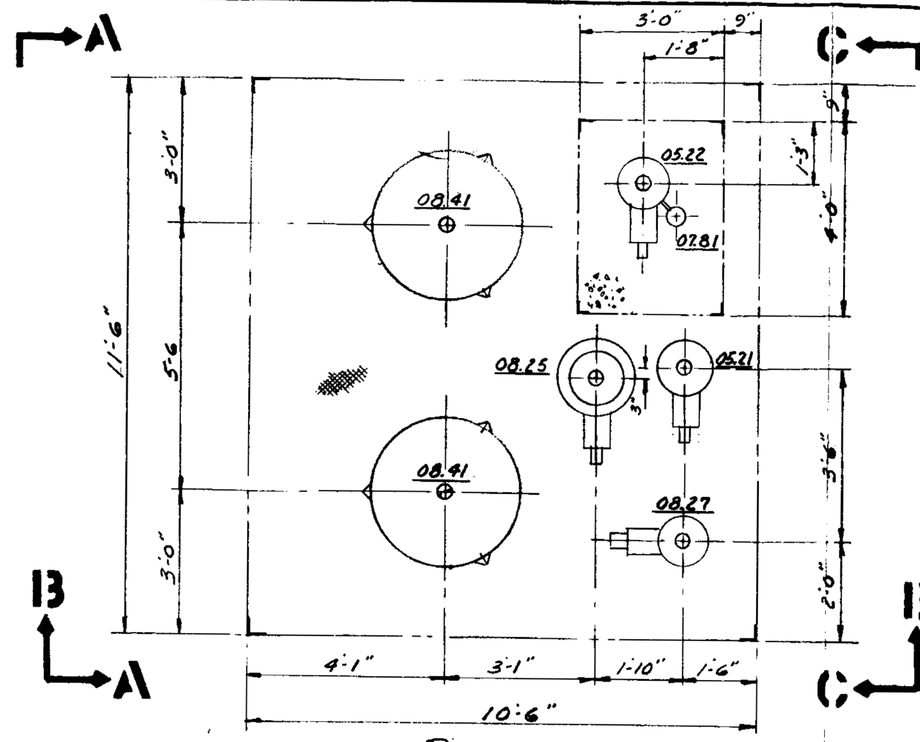
TITLE: PREL. COMPRESSOR BUILDING LAYOUT FOR HELIUM PURIFICATION EQUIP. NASA CONTRACT Nº NASA 10-1472

SCALE 1/8" = 1'-0" WT.

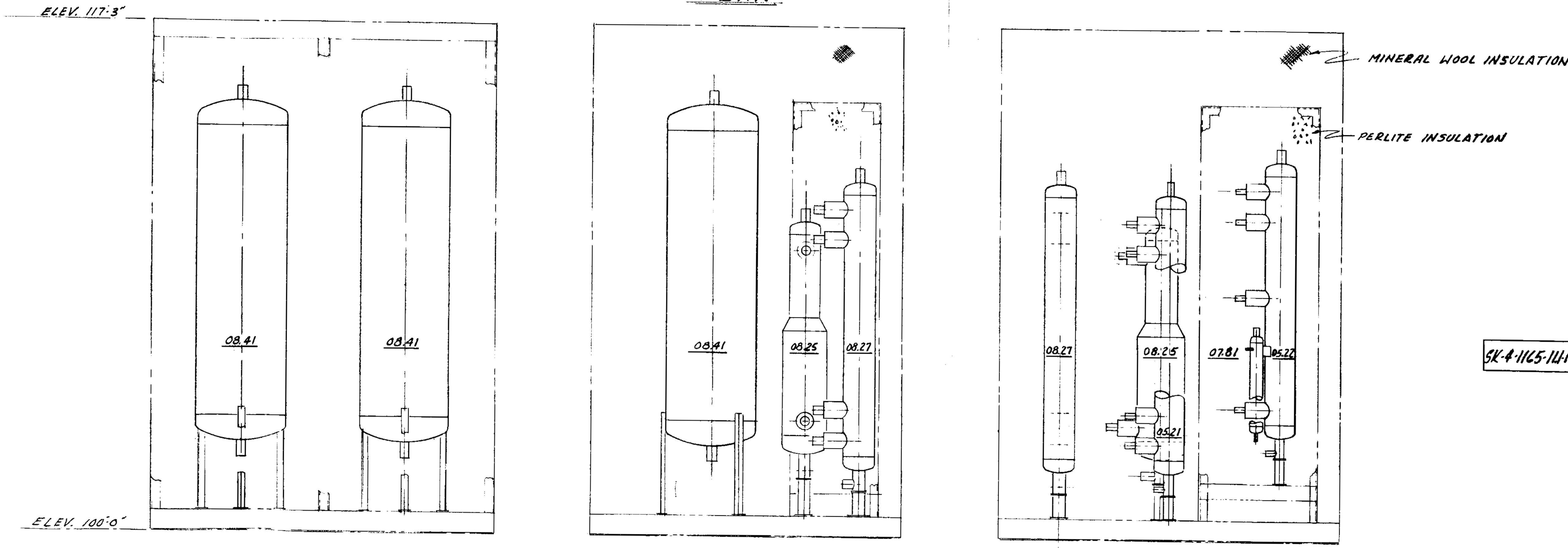
AIR PRODUCTS AND CHEMICALS, INC.
ALLENTOWN, PENNSYLVANIA

CODE CONTROL NUMBER

SK-4-1165-57-1 D



PLAN



ELEVATION A-A

ELEVATION B-B

ELEVATION C-C

REVISIONS							
NO.	LETTER	ZONE	DESCRIPTION	DATE	MADE	CHK'D	APPR'D

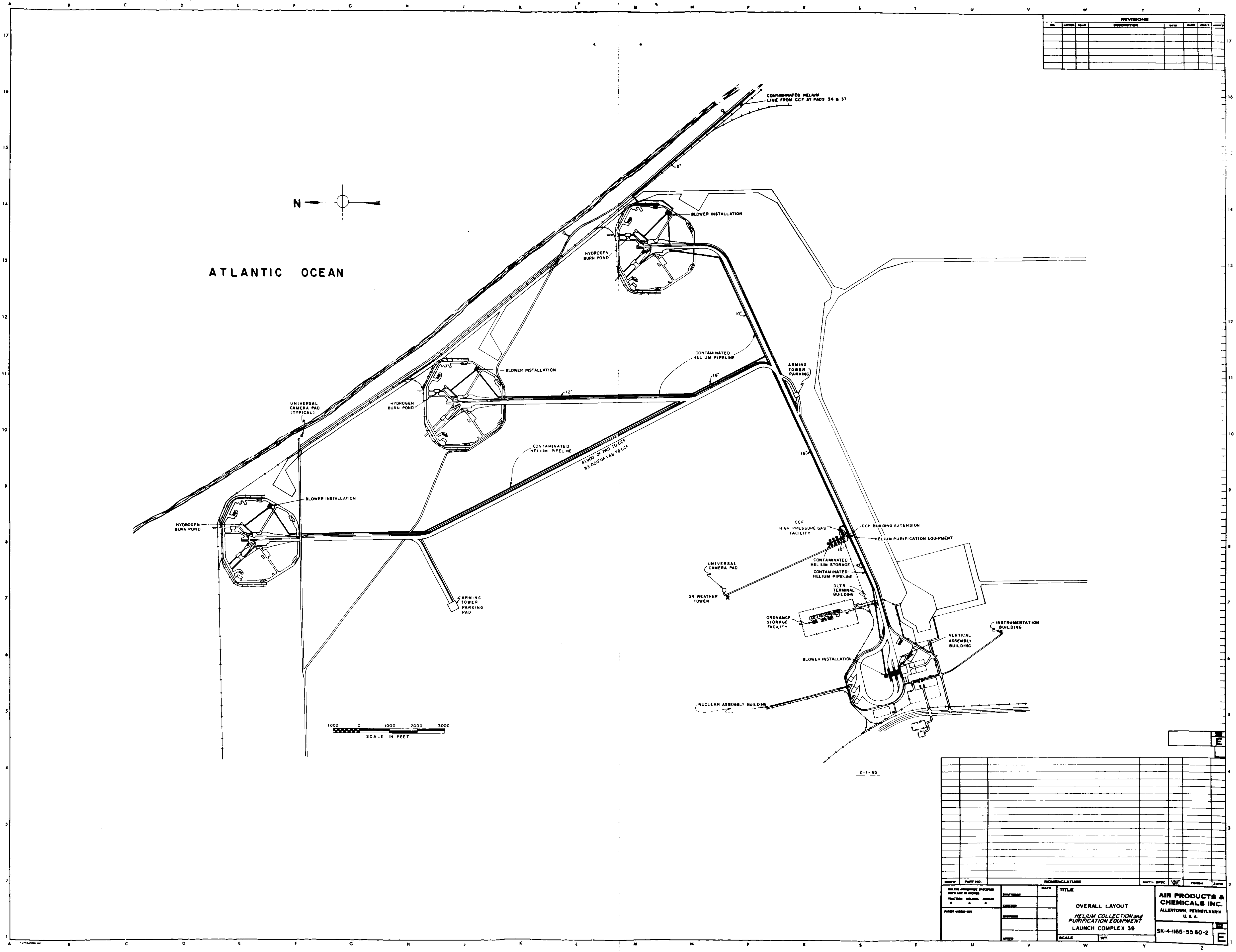
LEGEND

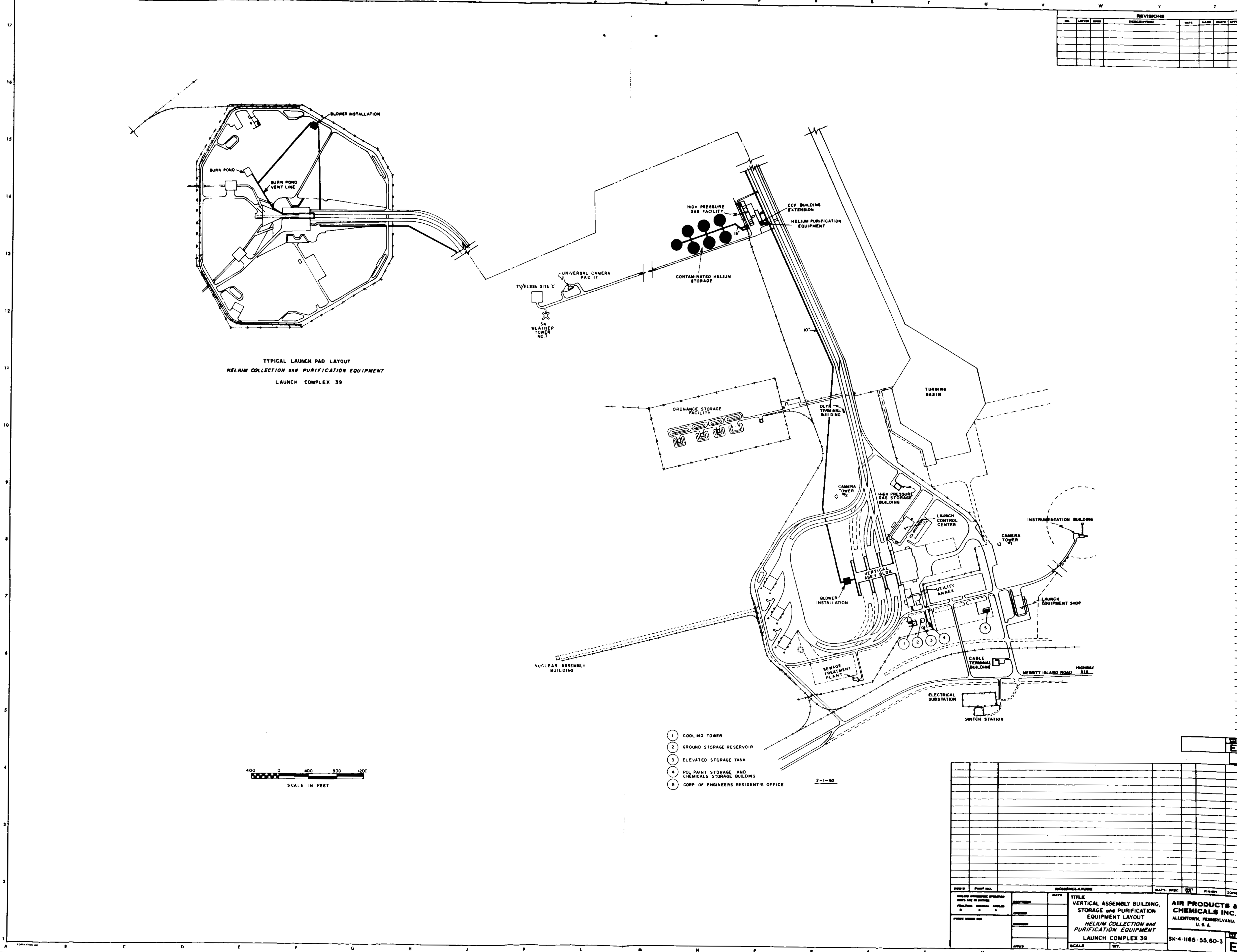
05.21 MAIN EXCHANGER
05.22 COLD EXCHANGER
07.81 N_2 LIQUID SEPARATOR
08.25 ADSORBER COOLDOWN EXCHANGER
08.27 ADSORBER COOLDOWN ECONOMIZER EXCH.
08.41 N_2 ADSORBER

SK-4-1165-11.1-1 D

PART NO.	MAT'L. CODE NO.	QTY.	DIMENSIONS	REMARKS	NOMENCLATURE

UNLESS OTHERWISE SPECIFIED TOLERANCES ARE FRACTION ± DECIMAL ± ANGLES ± HOLE LOCATION ± HOLE SIZE ±	DA/NAFER DRAFTSMAN	DATE 2-8-65	TITLE PREL COLD BOX LAYOUT FOR HELIUM PURIFICATION EQUIP NASA CONTRACT Nº NASA 10-1472	AIR PRODUCTS, AND CHEMICALS, INC. ALLENTOWN, PENNSYLVANIA
	CHECKED			CODE CONTROL NUMBER
FIRST USED ON 00-4-1165-11.1	ENGINEER			
	W.C. Luhne APPR'D	2/15/65	SCALE 1/2"=1'-0" WT.	SK-4-1165-11.1-1 D


ATLANTIC OCEAN
N
CONTAMINATED HELIUM LINE FROM CCF AT PADS 34 & 37
2"
BLOWER INSTALLATION
HYDROGEN BURN POND
10"
CONTAMINATED HELIUM PIPELINE
16"
12"
ARMING TOWER PARKING
UNIVERSAL CAMERA PAD (TYPICAL)
41,900' OF PAD TO CCF
83,000' OF VAB TO CCF
CCF HIGH PRESSURE GAS FACILITY
CCF BUILDING EXTENSION
HELIUM PURIFICATION EQUIPMENT
CONTAMINATED HELIUM STORAGE
CONTAMINATED HELIUM PIPELINE
DLTR TERMINAL BUILDING
UNIVERSAL CAMERA PAD
54' WEATHER TOWER
ORDNANCE STORAGE FACILITY
ARMING TOWER PARKING PAD
INSTRUMENTATION BUILDING
VERTICAL ASSEMBLY BUILDING
NUCLEAR ASSEMBLY BUILDING
1000 0 1000 2000 3000
SCALE IN FEET
2-1-65
REVISIONS
NOMENCLATURE
TITLE
OVERALL LAYOUT
HELIUM COLLECTION and PURIFICATION EQUIPMENT
LAUNCH COMPLEX 39
AIR PRODUCTS & CHEMICALS INC.
ALLENTOWN, PENNSYLVANIA U. S. A.
SK-4-1165-55.60-2
E



REVISIONS
BLOWER INSTALLATION
BURN POND
BURN POND VENT LINE
TYPICAL LAUNCH PAD LAYOUT
HELIUM COLLECTION and PURIFICATION EQUIPMENT
LAUNCH COMPLEX 39
HIGH PRESSURE GAS FACILITY
CCF BUILDING EXTENSION
HELIUM PURIFICATION EQUIPMENT
16"
CONTAMINATED HELIUM STORAGE
UNIVERSAL CAMERA PAD 17
TV/ELSSE SITE 'C'
54' WEATHER TOWER NO.7
10"
TURNING BASIN
ORDNANCE STORAGE FACILITY
DLTR TERMINAL BUILDING
CAMERA TOWER #2
HIGH PRESSURE GAS STORAGE BUILDING
LAUNCH CONTROL CENTER
INSTRUMENTATION BUILDING
CAMERA TOWER #1
VERTICAL ASS'Y BLDG
BLOWER INSTALLATION
UTILITY ANNEX
LAUNCH EQUIPMENT SHOP
NUCLEAR ASSEMBLY BUILDING
SEWAGE TREATMENT PLANT
CABLE TERMINAL BUILDING
MERRITT ISLAND ROAD
HIGHWAY A1A
ELECTRICAL SUBSTATION
SWITCH STATION
1 COOLING TOWER
2 GROUND STORAGE RESERVOIR
3 ELEVATED STORAGE TANK
4 POL PAINT STORAGE AND CHEMICALS STORAGE BUILDING
5 CORP OF ENGINEERS RESIDENT'S OFFICE
2-1-65
400 0 400 800 1200
SCALE IN FEET
NOMENCLATURE
TITLE
VERTICAL ASSEMBLY BUILDING, STORAGE and PURIFICATION EQUIPMENT LAYOUT
HELIUM COLLECTION and PURIFICATION EQUIPMENT
LAUNCH COMPLEX 39
AIR PRODUCTS & CHEMICALS INC.
ALLENTOWN, PENNSYLVANIA U.S.A.
SK-4-1165-55.60-3
E